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Methodology for BIM implementation in KSA in AEC industry

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Abstract

Recently, the Architecture, Engineering, and Construction (AEC) industry is considered the most effective contributor to development in the Kingdom of Saudi Arabia (KSA). However, the AEC industry is facing myriads challenges due to the vast construction development required for the KSA 2030 vision. Many issues are raised such as failure to meet the client requirement, delay in delivering projects in time, cost overrun, low quality, conflicts among parties, shortage of qualified workers, safety issues, increasing requests of change order, increasing in material wastes and project complexity. Developed countries are using Building Information Modeling (BIM) to mitigate these challenges and reap the benefits from implementing BIM to improve the performance of the AEC industry profoundly.

BIM is rapidly growing worldwide as a viable tool for improving the efficiency of (AEC) industry. However, BIM is rarely used in the KSA. The proved benefits of implementing BIM in the developed countries, gave evidence that, BIM requires drastic change and there is no recognized methodology to solicit companies to use BIM. However, from these countries, experience BIM must be mandated. There are some timid attempts to decree BIM in the Gulf Council Countries (GCC) region, whereas in 2014, Dubai Municipality mandate BIM in the large projects.

This study aims to develop a methodology to implement BIM in the KSA by exploring the stockholders' perception of BIM benefits, barriers, and factors affecting the adaption. Accordingly, a questionnaire has been sent to many BIM users and non-users. In addition to, structured interviews were carried out with BIM users and non-users. In the efforts to validate the proposed methodology, another survey sent to BIM experts and structured interviews have been organized with BIM professionals. SPSS 23 software used to analyze quantitative data and NVivo 10 used to analyze qualitative data.

The key findings of this study are: (1) Identifying the six steps of the methodology in details in its order to implement BIM; (2) Raising awareness; (3) Perceived benefits of BIM; (4) AEC industry readiness and organizations capability; (5) identifying the barriers; (6) Removing the barriers; and (7) Defining the key factors influencing the implementation. The results of this research are expected to assist all projects participants in KSA to implement BIM to solve the current AEC industry projects issues, improve the performance of the project and reap the benefits of implementing BIM. This study is the first research to make a crucial and novel contribution by providing a methodology to implement BIM in KSA. Future studies can validate the methodology for each project parties.

Keywords: BIM, KSA, AEC, Barriers, Benefits, Adoption, implementation

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Dedication

“And say, oh my Lord increase my knowledge”

I dedicate this dissertation

To my Mother, “Eman Abo EL fadl”

,

To my Father, “Ibrahim El hendawi”

“Our Lord, have mercy on our parents, even as they had mercy on us, while we were little!”

,

To my wife “Fatma Motawee”

And

To my daughters “Farida and Alia Ashraf Nasr”

Ashraf Nasr Elhendawi

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List of Abbreviations

AEC: Architecture, Engineering, and Construction
AIA: American Institute of Architects
BIM: Building Information Modeling
BREEAM: Building Research Establishment Environmental Assessment Method
CRC: The Cooperative Research Centre for Construction Innovation
CAD: Computer Assisted Design/Computer Aided Drafting
DM: Dubai Municipality
FM: Facility Management
GDP: Gross Domestic Products
IPR: Intellectual Property Rights
IFC: Industry Foundation Class
ICT: Information and Communication Technology
IFC: Industry Foundation Classes
Imp: Impact
IAI: International Alliance for Interoperability
IPD: Integrated Project Delivery
JIT: Just In Time
KSA: Kingdom of Saudi Arabia
KPI: Key Performance Indicator(s)
LEED: Leadership in Energy and Environmental Design
MENA: Middle East and North Africa
M: Mean
MEP: Mechanical, Electrical, and Plumbing
n-D: number-Dimensions
NBIMS: National Building Information Modeling Standards
O&M: Operation and Maintenance
PPP: Public-Private Partnership
PWA: Public Work Authorities
Prob: Probability
RFID: Radio Frequency Identification
ROI: Return on Investment
SD: Standard Deviation
VDC Virtual Design and Construction
2D: Two dimensions: x, y
3D: Three dimensions: x, y, and z
4D: Three Dimensions plus Time Information
5D: Four Dimensions plus Cost Information

List of Symbols

% …… Percent

Chapter 1: Introduction

1.1 Introduction

The AEC industry is considered the backbone of the economy for nations (Eastman, 1975). Consequently, the AEC industry impacts severely the nations' growth (Adams, 2004; Giang & Pheng, 2011).

For decades, the AEC industry has been suffering from a plethora of problems and stay lagging behind other industries. Clients' requirements are not achieved, usually, projects are delivered beyond schedule, over budget with low quality (Latham, 1994; Egan, 1998). AEC suffering less productivity, poor efficiency, ineffective performance, low support to sustainability (Azhar, et al., 2015), insufficient environment protection, poor working conditions and inefficient safety management (Latiffi, et al., 2013).

Recently, the construction industry has become more complex to be managed. This is due to technical complexity, various data to be managed, supply chain problems, contractual provision (Hyari, 2005), and demand to a smart and green building (Marzouk, et al., 2014).

Last century witnessed increasing of the population worldwide, accordingly, infrastructure, environmental, residential, commercial, industrial and health-care projects are crucially required. Therefore, the traditional methods fail to respond to these needs and project objectives tend to fail (Alshehri, 2013). The convention construction methods cause losing data, misunderstanding, and slippage in projects durations and budgets (Azhar, et al., 2015). So, to achieve projects' objectives (i.e. time, cost, quality, client satisfaction, sustainability, etc.), the collaboration between all projects stockholders should be enhanced (Krygiel & Nies, 2008; Grilo & Jardim-Goncalves, 2010; Latiffi, et al., 2013). Many researchers investigated feasible solutions of the aforementioned (Latham, 1994; Egan, 1998).

Latham (1994) concluded that, due to the lack of communication and poor collaboration between the AEC industries key players, accordingly, the innovative solutions cannot be adopted. in the last decade, AEC industry players have been clinging to the old ways of working, consequently, that resulted in less responsive to new technologies (National Research Council (US), 1988; Dulaimi, et al., 2002).

Thus, all parties must integrate with each other to work collaboratively to adopt a creative and innovative solution and rethinks to abandon the old methods that are no longer the best ways and Keep up with the latest technologies. Moreover, this will help achieve the projects' aims and objectives in order to meet the client and user satisfaction (Love, et al., 2013; Jernigan, 2014).

Several researchers introduce BIM as a valuable tool to enhance the communication and collaboration between the AEC industries key players (McGrawHillConstruction ،2014 ؛Gerges, M, et al. ،2017 ؛Matarneh & Hamed ، 2017).

Roots of BIM back to the parametric modeling produced in the USA in the 1970s and the parametric modeling conducted in Europe in 1980s, however, the AEC industry started to use BIM in its projects on 2000s. Since then many companies and governments all over the world have been trying to find ways to adapt and reap BIM benefits (Eastman, et al., 2011).

Developed countries have recognized the benefits of BIM and considered BIM as the AEC's future language that all the AEC organizations worldwide have to implement. This is evident from the rapid growth of BIM and mandates being issued in several countries such as the UK, where government planned on 2011 to mandate BIM in its AEC industry by 2016, similarly USA, and Europe (Cabinet Office and The Rt Hon Lord Maude of Horsham, 2012; Eadie, et al., 2013). However, developing countries are still in the early stages to explore BIM and try to find appropriate practical strategies for adoption (Chan, 2014).

1.2 Research motivations

Research motivation can be summarized as searching for solving some of the problems facing the AEC industry in KSA through applying BIM. Furthermore, as a technology expert, Stewart Brand mentioned that "Once a new technology rolls over you, if you are not part of the steamroller, you are part of the road" (Brand, 1987). As such, KSA must keep up with the new technology.

Personal motivation is exploiting the new technology which achieved impressive results in the same field in other countries and to develop my skills and keep up with the latest technology.

1.3 The Problem statement

The AEC industry is facing myriads of functional gaps among its parties. This starts with the client's early perception passing to predesign and the design stages, construction, Operation, and Maintenance (O&M) until the demolishing of the building.

Researchers and management professionals tried to bridge the recognized gaps of the AEC industry such as teamwork fragmentations, ineffective coordination, poor communications, buildings low performance, energy overconsumption, unsustainable buildings (Latham, 1994; Egan, 1998). In addition to design errors and clashes, project overrun, low productivity, low building quality, the poor satisfaction of stakeholders /client/users and shortage or unauthenticated data for

Facility Management (FM) during maintenance stage (Eastman, et al., 2008; Arayici, et al., 2012).

Boom in the KSA applied tremendous pressures on its AEC industry. Therefore, there is an urgent need to adopt the latest technologies and management strategies to eradicate the recognised problems and to improve the performance of the AEC industry (Alhumayn, et al., 2017). In addition to responding to the increasing demands for smart buildings and government's concerns of the continuous developments.

The AEC industry in many developing countries still facing lack of attention from the decision makers concerning the implementation of BIM. Projects' parties in KSA think that BIM benefits are not clear because of the limited researching on BIM in KSA (Almutiri, 2016).

1.4 Aim and Objectives

This dissertation aims to find a methodology to implement BIM in KSA trying to solve the current KSA AEC industry projects salient issues to improve the performance of the projects and reap the benefits from BIM. To achieve this aim, the following objectives are identified:

1. Explore the level of awareness about BIM in the KSA AEC industry and Propose solutions to raise awareness about BIM in the KSA AEC industry.
2. Investigate the perceived benefits of BIM in the KSA AEC industry.
3. Determine the barriers deterring BIM implementation in the KSA AEC industry.
4. Propose solutions to overcome the barriers that diminishing BIM implementation.
5. Explore the main driving forces and the external pressures pushing the implementation of BIM in the KSA AEC industry.
6. Identify the main internal forces influencing BIM implementation in KSA AEC industry.
7. Investigate the AEC industry readiness, and the organization's capabilities to implement BIM.
8. Propose a solution to KSA government to enable the mandate of BIM.

1.5 Dissertation Questions

The research questions addressed in the study were shaped by the gaps identified in the extant literature and can be broadly categorised as follows:

Q1: What is the level of awareness about BIM in KSA AEC industry?
Q2: How can the awareness about BIM be raised in KSA AEC industry?
Q3: What are the perceptions of the KSA AEC industry professionals for the benefits of BIM?
Q4: What are the main barriers hinder the BIM implementation in KSA AEC industry?
Q5: How can the project participants overcome the main barriers that block the BIM implementation?
Q6: What are the main driving forces and the main external pressures pushing the implementation of BIM in the KSA AEC industry?
Q7: What are the main internal pushes to facilitate the implementation of BIM in the KSA AEC industry?
Q8: What is the AEC industry readiness, and the organization's capabilities to implement BIM?

1.6 Scope of research

The scope of this research limited to exploring and investigating the awareness about BIM in KSA AEC industry, benefits that gained from implementing BIM, barriers that hinder the BIM implementation, the main factors expediting the BIM implementation and the readiness of the AEC industry organizations to implement BIM.

1.7 Research methodology

The research methodology consists of three phases:

First phase: an extensive literature review to build a broad understanding to cover the stipulated research scope.

Second phase: questionnaire survey to collect the BIM user and non-user perceptions about each step that produces the suggested methodology to implement BIM in KSA.

Third phase: questionnaire survey and structured interviews to validate the proposed methodology to implement BIM in KSA AEC industry projects from only BIM user's perspectives. The quantitative data (from the two questionnaires) analyse by SPSS 23 software, and a qualitative one (some from developed models questionnaire and the other from the interviews) analyse by NVivo 10.

1.8 Key findings and Contributions

This study is the first research to provide a novel contribution to investigate the key factors influencing and expediting the BIM implementation in KSA AEC industry and provide a suggested methodology for implementing BIM in KSA.

1.9 Structure of the research

The study was divided into six chapters followed by appendices. Chapter one includes an introduction, the problem statement, aim and objectives, research motivation, the scope of research, research methodology, key findings and contributions, and structure of research. Chapter two encompasses literature review of previous studies in BIM. Chapter three describes research methodology and data collection. Chapter four includes the results and its analysis. Chapter five describes proposed model for BIM implementation and its validation. Finally, chapter six provides conclusion and recommendations, summarising results and main findings, research limitations, and recommendations for further researches.

Chapter 2: Literature Review

2.1 Overview

For decades the AEC industry has been suffering from its inefficiency, poor productivity and low performance (Egan, 1998; Leeds, 2016). (McGraw-Hill, 2012) Has compared the productivity between the construction industry and the non-farm industries from1964 till 2004 in the USA. Figure (1), illustrates the discrepancy between the AEC and the non-farm labor productivity.

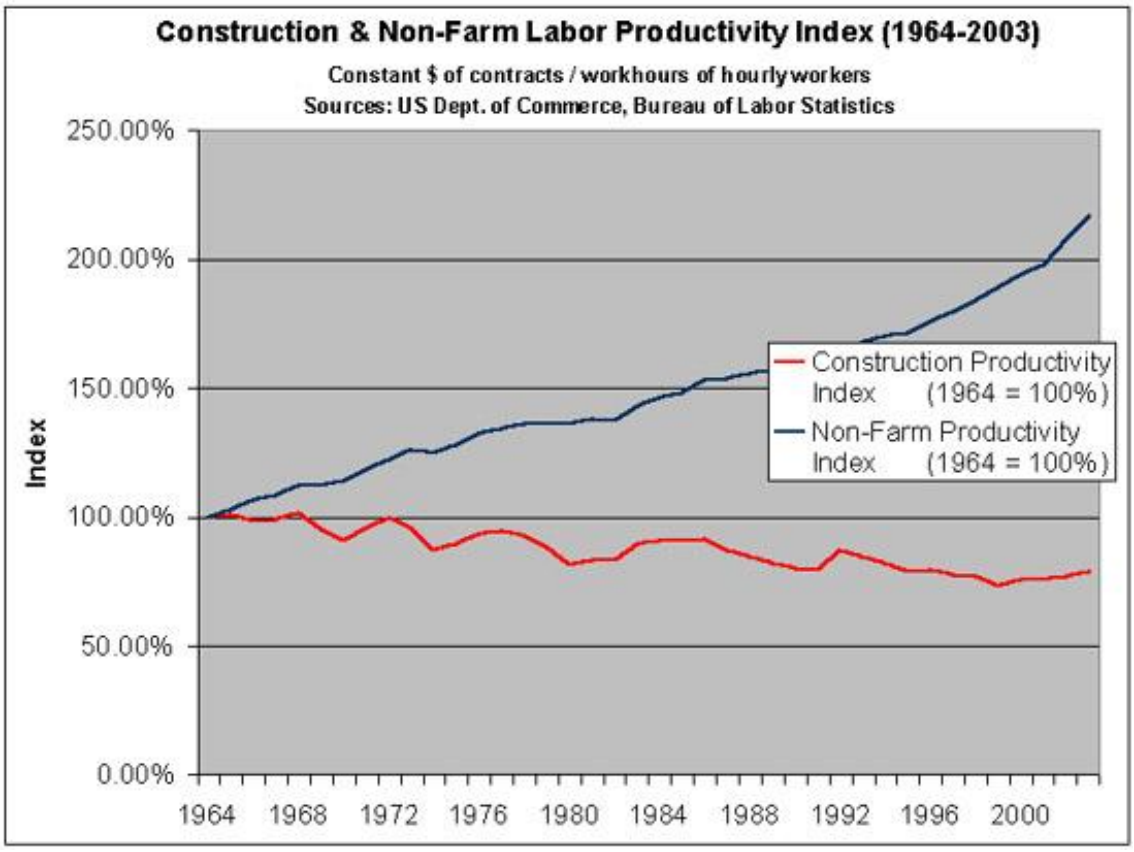

Figure 1: Construction & non-farm labor productivity index (McGraw-Hill, 2012)

Therefore, there is a crucial need to steer the AEC industry towards a real paradigm shift to increase the efficiency, productivity, enhance money value, improve quality, and promote the sustainability (Latham, 1994; Egan, 1998; Baiden & Price, 2011; Baiden, et al., 2006).

The current conventional practices in the AEC industry usually create different interests among the project parties. On one hand, governments and clients are usually concerned about quality improvement with reducing construction time, cost, and increasing the quality. However, contractors and architects are interested in business improvements to increase their profits, promote their

competitive advantages and meeting client satisfaction to get sustained in the rival markets (Azhar, 2011).

The nature of the construction industry is different from other industries, such as the manufacturing, the temporary nature, and uniqueness of construction projects is reflected in one-off nature for locations, designs solutions and project teams (Hore, 2006). Accordingly, poor management within AEC industry leads to a fragmented communication, as shown in Figure (2).

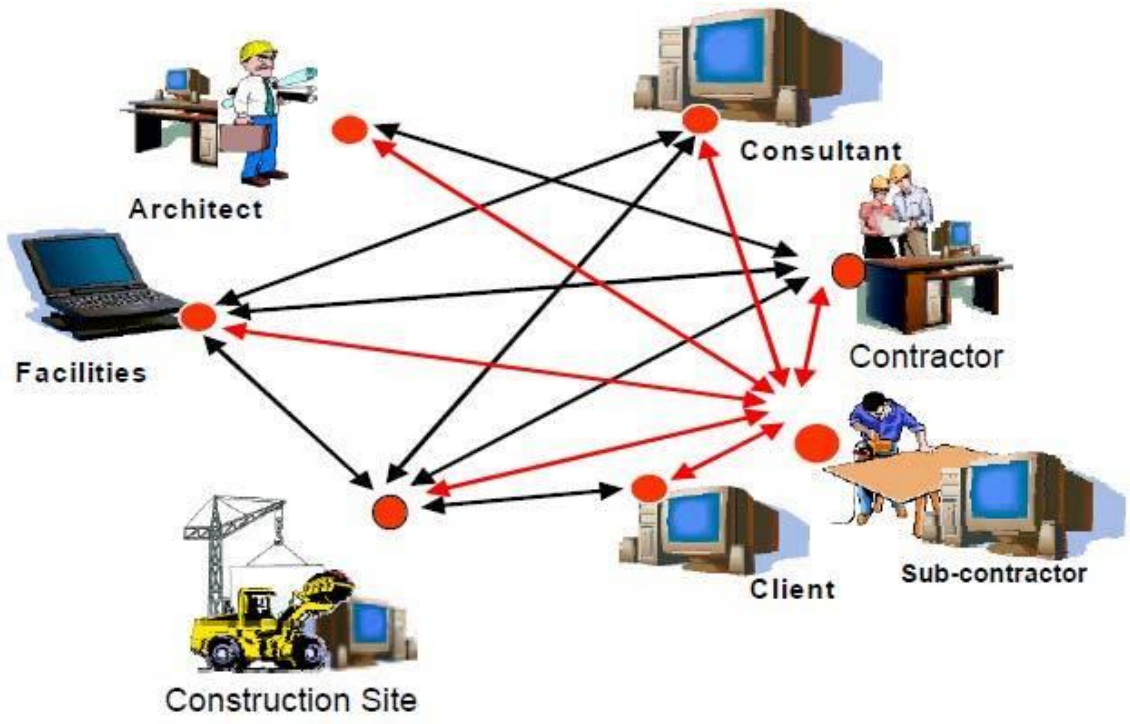

Figure 2: Fragmented nature of the construction industry (Hore, 2006)

Traditionally, the AEC industry projects became more complex to manage, because of its fragmented nature and its resistance to change (Latham, 1994; Egan, 1998; Williams, 2002; Alshawi & Ingirige, 2002; Hardin, 2009; Love, et al., 2013). Additionally, (Ofori, 2000) claimed that the main Challenges of AEC industry in developing countries include construction industry development, globalization, culture, the environment.

Enhancing the AEC industry was the prominent concern for various governments, entities, and academics (Almualim & Gilder, 2010). Many researchers and professionals have the consensus that the fragmented and conservative nature of the AEC industry hampered expedite responses to innovative technologies and minified the chances for improvements (Latham, 1994; Egan, 1998; Aouad & Sun, 1999; Dulaimi, et al., 2002; Carmona & Irwin, 2007; Barrett, 2008; Hardin, 2009; Baiden & Price, 2011).

Many researchers suggested improving the construction industry through continuous improvements and raising the capacity of people (the team),

technology and processes (Latham, 1994; Egan, 1998; Hardin, 2009; Love, et al., 2013). However, (McKenna, 2006) claimed that people are the most critical factor for any successful improvement in the industry because people are the decision makers and highly influence the other two areas i.e. the technology and the processes.

Currently, BIM proves its competency to improve AEC industry performance and enhance the coordination and collaboration between various project parties. BIM is considered a revolutionary technology and process management, proposed as the potential solution for the current issues in the AEC industry (Azhar, et al., 2008; Hardin, 2009; Liu, et al., 2010; Arayici, et al., 2011; Azhar, et al., 2011; Azhar, 2011; Azhar, et al., 2015; Bryde, et al., 2013; Love, et al., 2013; Love, et al., 2014).

2.1.1 AEC Industry in KSA.

In the last decade, there has been a significant growth within the Saudi Arabian construction sector which appears to be the second economic boom (Alhowaish, 2015; Banawi, 2017). KSA is one of the biggest and leading countries in the Middle East (ME) ahead of Turkey, Iran and neighboring Gulf countries. The construction sector is ranked second after oil in the Kingdom's economy and contributes approximately 8% of total Gross Domestic Product (GDP) (The Canadian Trade Commissioner Service, 2014; Deloitte, 2014). The value of its projects is more than one trillion US Dollars in residential, healthcare, education, and transportation (Deloitte, 2014). The recent 2030 vision plan that announced by KSA government, in 2016, forced all AEC sectors to be creative, efficient, and environmentally responsible.

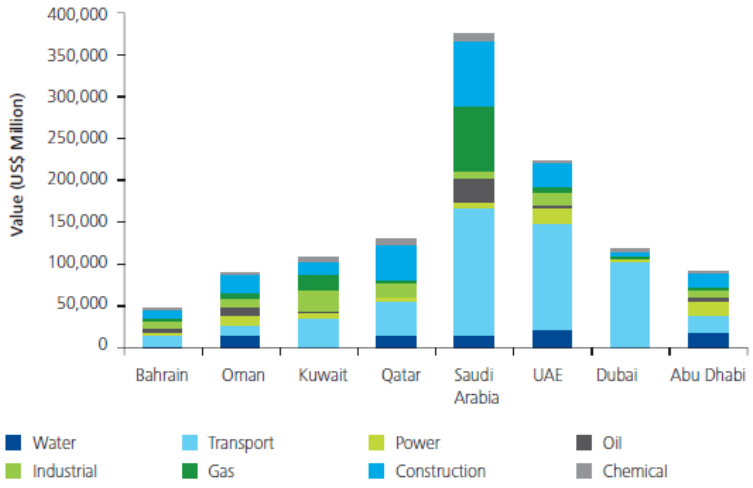

Figure 3: the forecasted Value of different types of projects for the period from 2014 to 2020 in the Middle East countries (Deloitte, 2014)

As shown in Figure (3), Saudi Arabia's market share in construction industry consider as the highest with 43% within Gulf Countries Council (GCC) (Deloitte,

2015). According to report published by Deloitte in 2013, new contracts awarded in 2012 were worth about $24bn and are expected to go up to $52bn in 2015, which represents about 10% of Saudi Arabia's Gross Domestic Product (GDP). According to market research, 75% of waste in the KSA comes from construction, and buildings are responsible for 40% of carbon emissions (Initiative, 2009). Therefore, a slight improvement in this sector could have a considerable impact on capital expenditure and environment (Banawi, 2017).

The housing sector, in particular, is likely to grow, as SA population is rising at a rate of 2.5 % a year. Construction will also play a large role in the SA's massive industrial expansion through the National Industrial Cluster Development Program as well as in the completion of six economic cities (COUNCIL, U.S.A.B., 2011).

Sample of mega projects in KSA are The Kingdom Tower project in Jeddah, The King Abdullah City for Atomic and Renewable Energy (KACARE) in Riyadh, The Saudi Green Building Council in Riyadh, Saudi Public Pension Agency or PPA, Jeddah Development and Urban Regeneration Company (JDURC), Arriyadh Development Authority (ADA) in Riyadh and Colleges of Excellence (CoE) in Saudi Arabia (The Canadian Trade Commissioner Service, 2014). Table (1) lists a number of mega projects under execution in KSA.

Table 1: Mega projects under execution in Saudi Arabia (MEED Projects)

Project	**Client**	**Estimated value ($m)**
King Abdullah Economic City	Emaar, The Economic City	93,000
Saudi housing program	Housing Ministry	70,000
Sudair Industrial City	Saudi Industrial Property Authority (MODON)	40,000
Jizan Economic City	Saudi Arabian General Investment Authority (SAGIA)	40,000
Riyadh Metro	Arriyadh Development Authority	22,480
Sadara chemical complex, Jubail	Sadara Chemical Company	20,000
Kingdom City	Kingdom Holding	20,000
Haramain high-speed rail network	Saudi Railways Organization	13,743
Security compounds	Interior Ministry	13,000
Yanbu Aramco Sinopec refinery	Yanbu Aramco Sinopec Refining Company	10,000
Maaden/Alcoa aluminium complex	Saudi Arabian Mining Company (Maaden)	9,900
Manifa Arabian heavy crude program	Saudi Aramco	9,280
King Abdulaziz International Airport	General Authority of Civil Aviation	8,172
Knowledge Economic City in Medina	Knowledge Economic City Company	8,000
Sipchem complex phase 3, Jubail	Saudi International Petrochemical Company(Sipchem)	7,860

Waad al-Shamal Phosphate City)	Mosaic/Saudi Basic Industries Corporation (SABIC	7,225
King Abdullah Financial District	Rayadah Investment Company	7,000
PetroRabigh phase 2	Rabigh Refining and Petrochemical Company (PetroRabigh)	7,000
Wasit Gas Development	Saudi Aramco	5,000
Jabal al-Kaaba	Abdul Latif Jameel Real Estate Investment Company	2,666

Neum project according to KSA vision 2030 is a private zone that includes land within the Egyptian and Jordanian borders. It will exceed $ 500 billion, sharing between local and international investors. The largest part of the project is located in the northwest of the KSA, covering an area of 26,500 km^2, overlooking the North and West on the Red Sea and the Gulf of Aqaba with a length of 468 km. (Alarabiya News, 2017).

2.1.2 Challenges for construction industry in KSA

As one of the world's largest producers and exporters of oil, and a fast expanding and diverse economy, KSA earns a global focus and how it is likely to perform under the recent drastic falling of oil prices hitting $50 per barrel in January 2015, the lowest since 2009. (Ventures Middle East, 2015) This has caused many problems to the KSA government's projects. The rapidly growing population in KSA is tremendous applying pressures on existing infrastructure.

(Alsalim, 2013) claimed that KSA construction industry has been struggling from ineffective management and low organizational performance. As a result of the number of projects suffering from remarkable delays increased from 700 projects in 2009 to 3000 projects in 2013. Statistical studies in KSA showed that during the period between 1992 and 2009, 850 projects out of 1035 were experiencing delays and cost overruns, where, 41% exceeded the cost and 82% exceeded their delivery date (Al Riyadh newspaper, 2017). A large number of projects being put on hold, because of errors in projects' design, and ineffective supervision of all the parties in the projects (Alsalim, 2013). One main reason can be attributed to the lack of planning and design, this planning laxity is due to the poor management and inability to foresee the project buildability (Althynian, 2010). (Alshehri, 2013) explored that disputes concerning construction contracts, procurement, and design change orders are considered to be main causes of project conflict in AEC projects in Saudi Arabia. (Abdul-Hadi, et al., 2005) identified many inefficiencies in the Saudi construction industry, accordingly, he called for re-engineering the Saudi construction industry.

The KSA government has spent more money on their projects, sometime ten times of the estimated cost (Alhowaish, 2015). In addition to construction sector issues,

it has been stated that most of the local construction companies have a lack of knowledge, management, and experience in the project lifecycle (Jannadi, 1997).

Reasons for construction industry failures in Saudi Arabia are summarized as, bad judgment concerning project time and cost, lack of integration amongst project stakeholders, lack of management experience, low profit margins, lack of communication within companies, national downturns in the economy, poor management for disaster and unexpected bad weather (Jannadi, 1997; (Sobolewski, et al., 2016).

Construction projects are incorporating systems of digital sensors, intelligent machines, mobile devices and new software applicants that can be increasingly integrated with a central platform in a digitalized technology such as BIM. Hence, the outlook is an almost 20% reduction in total life-cycle costs of a project, as well as substantial improvements in completion time, quality, and safety (Castagnino, et al., 2016).

Many executives, as well as research institutions, confirmed that the use of BIM is of particular importance in the countries experiencing construction boom to improve the construction performance (Eastman, et al., 2011). KSA deemed one of those countries due to its huge number of projects. However, the number, size, cost, and complexity of projects in KSA which have suffered from many issues such as cost control, delays, lack of experts and discontinued projects are worthy for motivating the Saudi Government and construction companies to implement BIM (Almutiri, 2016).

2.2 Raising the BIM awareness

It is crucial for construction players to be aware of the importance of BIM in construction projects. This is because BIM can be one of the conditions required of a company to qualify for government and private projects (Latiffi, et al., 2013).

The following subsections enlighten the BIM definitions, comparing BIM against traditional method, introduce BIM deliverables, BIM Dimensions, BIM maturity, BIM applications, BIM status globally and future trends and what the lesson learn from the advanced BIM users, BIM tools, roles and responsibilities of BIM users, which organizations can use BIM and BIM SWOT analysis to raise the awareness of BIM.

2.2.1 BIM definitions:

BIM has been defined in various ways due to the area of expertise or to serve the definer's aim (Aranda-Mena, et al., 2009; Abbasnejad & Moud, 2013; Almutiri, 2016).

However, (Penttilä, 2006; Ernstrom, et al., 2006; Eastman, et al., 2008; Gerber,

et al., 2010; Sacks, et al., 2010; Azhar, 2011; Jung & Joo, 2011; Barlish & Sullivan, 2012) defined BIM as a group of interacting policies, software, processes and technologies, (Associated General Contractors of America (AGC), 2005; Succar, 2009; Sacks, et al., 2010; Gu & London, 2010; Arayici & Aouad, 2010; Azhar, et al., 2015) claimed that BIM focuses on applying information technology (IT).

Whereas, (Hardin, 2009; Building SMART, 2010; Eastman, et al., 2011; Omar, 2015) defined BIM as a process that digitally manages the design, construction, and O&M, (Barlish & Sullivan, 2012; Azhar, et al., 2015). (Azhar, 2011) Defined BIM as a virtual process that involves all aspects, disciplines, and systems of a facility within a single model that is shared with all stakeholders across the project lifecycle. (Sabol, 2008) Defined BIM as a sophisticated software tool that helps to record information and to assist with its components.

While, (NBIMS, 2007; Lee, 2008; Sebastian, 2011; BIM Industry Working Group, 2011; Chen & Qu, 2011; Teicholz, 2013; Nagalingam, et al., 2013; Sattineni & Macdonald, 2014) emphasis that BIM is an integrated model in which process and product information are combined, stored elaborated and interactively distributed to all relevant building participants.

As stipulated in Figure 4 (Abas, 2016) summarized the BIM as new technology, intelligent design information in 3D model-based process can demonstrate the entire building lifecycle that provides coordination source of structured information and presentation of the actual parts and places.

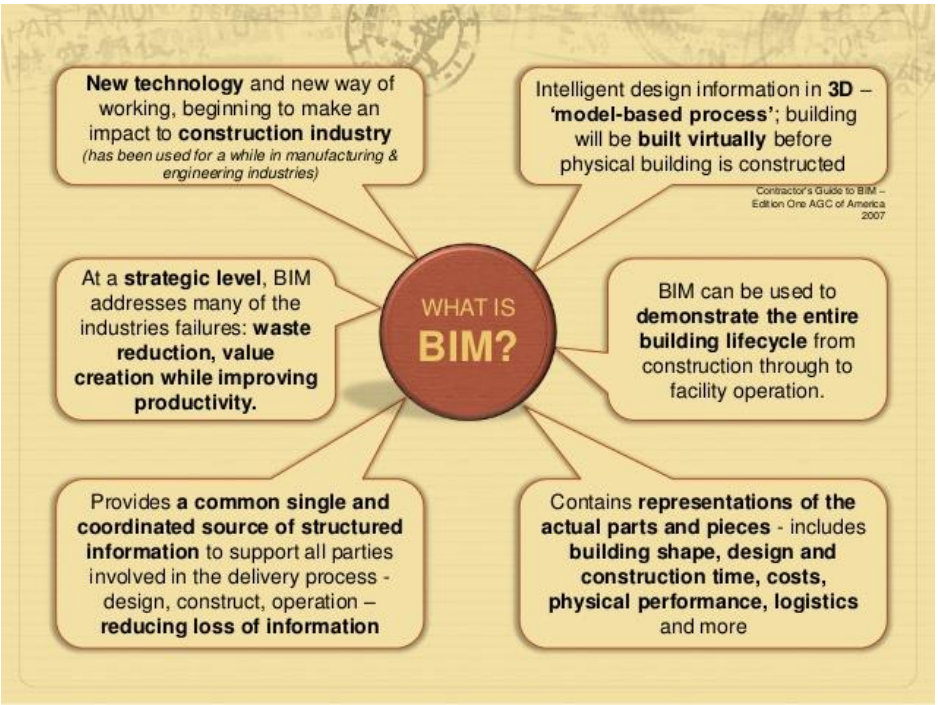
New technology and new way of working, beginning to make an impact to construction industry
(has been used for a while in manufacturing & engineering industries)
Intelligent design information in 3D – 'model-based process'; building will be built virtually before physical building is constructed
Contractor's Guide to BIM – Edition One AGC of America 2007
At a strategic level, BIM addresses many of the industries failures: waste reduction, value creation while improving productivity.
WHAT IS BIM?
BIM can be used to demonstrate the entire building lifecycle from construction through to facility operation.
Provides a common single and coordinated source of structured information to support all parties involved in the delivery process - design, construct, operation – reducing loss of information
Contains representations of the actual parts and pieces - includes building shape, design and construction time, costs, physical performance, logistics and more

Figure 4: What is BIM? (Abas, 2016)

2.2.2 Comparison between the traditional method process and the main concept of the BIM process:

The transition from the traditional method to the BIM concept requires dramatic changes in many disciplines such as software and hardware upgrade, changes in processes, and changing the organisational culture to reap BIM benefits. Figure (5), illustrates the comparison between the conventional method process and the main concept of the BIM process through different project phases. In the traditional methods, the considerable impact occurs in the construction documentation phases which in turn cause several issues to arise, delaying the project delivery and increasing the overall project cost. However, BIM process solves these issues at an early stage (Almutiri, 2016).

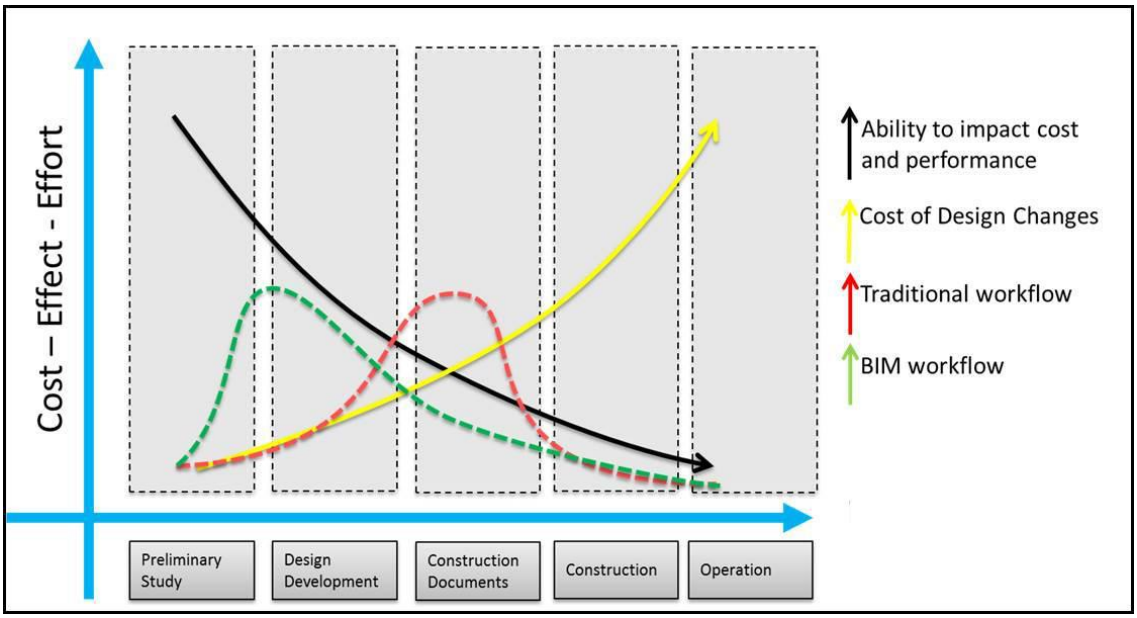

Figure 5: The value of BIM for the design process (Almutiri, 2016)

(Almutiri, 2016) claimed that the traditional methods suffer from many issues such as lack of project understanding, poor communication and data loss, problems in sharing information and poor collaboration between team members. (Duell, et al., 2013) illustrated in Figure (6) the difference between the BIM and traditional methods in sharing data.

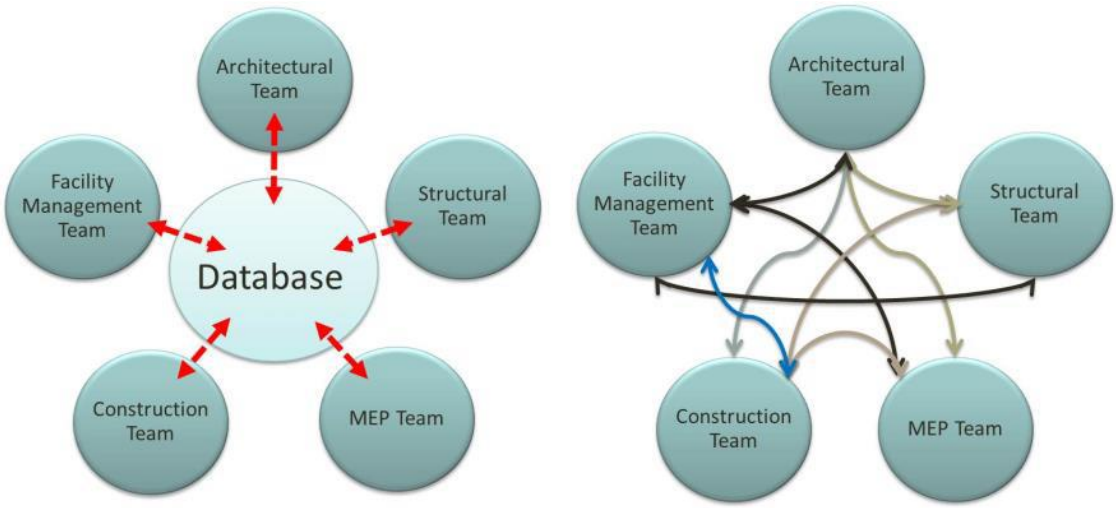

Figure 6: The difference between BIM and traditional method of sharing data (Duell, et al., 2013)

While the traditional 2D CAD program relies on sharing data in the form of paper-based practices, BIM shares the data in 3D environmental (Almutiri, 2016).Computer Aided Design (CAD) is no longer just about drafting. According to (LONG, et al., 2009) CAD is the greatest advancement in the construction industry in recent decades. Many BIM based-software solutions allow you to explore and evaluate project's constructability before it's built, improve cost reliability, visualise construction processes through 4D simulation and clash detection, increase coordination between stakeholders throughout the design and construction process, and better predict, manage and communicate project outcomes (Autodesk Design Academy, 2017).

The AEC traditional method that is using 2D CAD is a linear process, where the architect finishes the conceptual design then other disciplines finished the final design after collecting the required approvals from different stakeholders. The main constructor receives this final design to starts the construction and when the construction is completed, and the constructor has handed over the as-built to the client who in turn should deliver it to FM team. In this liner process, the next stage cannot commence unless the previous is finished, which requires close following up to deliver the task from one party to another. These linear processes hinder the collaboration between various project teams and require the client to be the project champion to pursue the successful delivery of each process (Love, et al., 2014), however, BIM provides cycle and overlap process.

In the conventional method, most clashes are determined at construction stage. However, BIM identifies clashes among various designs, early in the conceptual design phase, and before construction gets started that save time and money besides promoting the money value and efficiency (Abbasnejad & Moud, 2013).

Therefore, there is a crucial need to change to adopt a technology that can overcome all the aforementioned weaknesses during the design stages. That is directly steering to the implementation of BIM, to produce an error-free design. The BIM model is replete with electronic information that is ready to be transferred between the project players in an open platform. Project teams such as architects, designers (structural and MEP), sustainable analysts, contractors, and suppliers can extract and reuse the data and modify it to form the BIM model (Porwal & Hewage, 2013; New Zealand, B.I.M, 2014).

2.2.3 BIM deliverables:

(Gerges, M, et al., 2017) summarized BIM functions and duties as; (1) Models analysis for coordination, safety, clash detection and environmental concerns (energy, day lighting etc.); (2) Training others on BIM usage (colleagues, subordinates, subcontractors, owners etc.); (3) Extracting estimates from BIM models; (4) Creating 2D plans using CAD-Drafting; (5) Creating 4D schedule sequencing; (6) Creating site logistics plans and/or models; (7) Assisting in making decisions about new hardware, software or processes; (8) Testing new software; (9) creating marketing materials related to BIM (includes visuals, animations, written response to RFPs etc.); (10) Setting up jobsites with BIM; (11) prepare facilities management ready model.

(Abas, 2016) concluded that BIM deliverables are creating 3D modeling, clash analysis and detection, construction simulation, as built model and FM management (Figure 7).

(NBS, 2016) concluded the Key BIM deliverables for Level 2 that a contractor would be expected to produce include compliance with Employers Information Requirements (EIR), BIM Execution Plan (BEP), Common Data Environment (CDE), BS (PAS) 1192 - parts 1 to 5, classification (through Uniclass 2015), digital plan of work (describing Level of Detail – LoD / CIC Work Stages), intelligent 3D libraries, intelligent 3D models, 3D based collaboration, 3D digital survey, asset performance optimization and Construction Operations Building Information Exchange (COBie). Furthermore, additional deliverables that are not as part of BIM Level 2 but will become increasingly included contractor's information requirements, clash prevention, 3D model validation, 3D model take-off, 3D model based meetings and 4D/ 5D modeling.

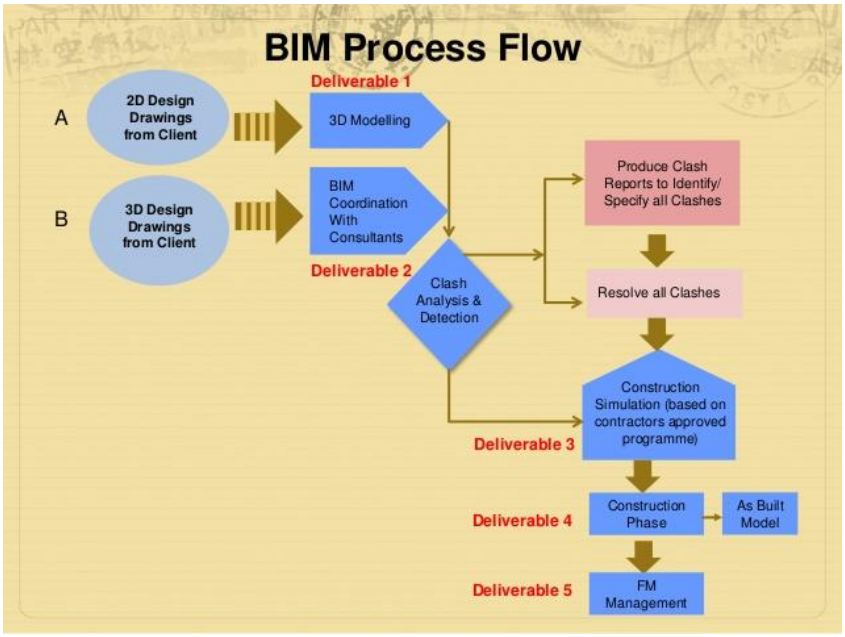

Figure 7: BIM Deliverables (Abas, 2016)

2.2.4 BIM Dimensions:

BIM is not just defined as a 3D model; it also includes the capability of transmitting plus reusing of the information embedded in it (Almutiri, 2016).

Adding more 'dimensions' of data to the information models (3D) enhance clear understanding of the construction phase: the durations concerns 4D model, cost 5D, sustainability 6D, and Operation and maintenance/Facility Management (FM) 7D model. Adding extra information can make more timely decisions and, ultimately, better buildings (McPartland, 2017). Until now researchers and professionals ensure that BIM provides 7D, as illustrated in Figure (8), as following:

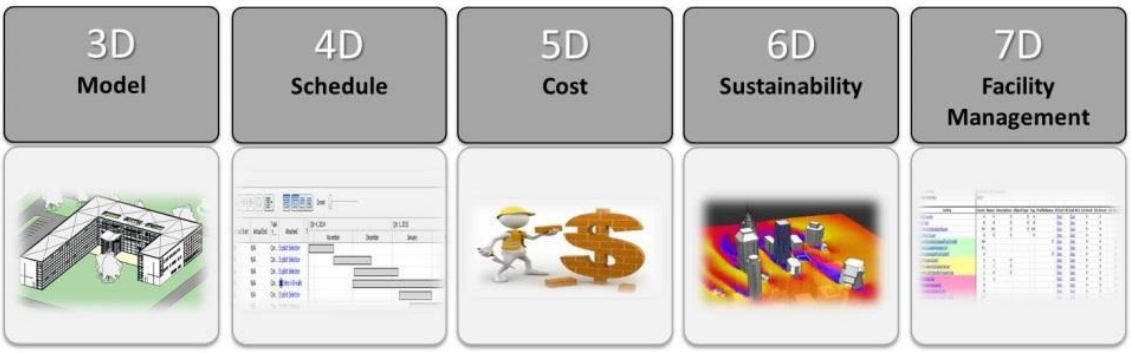

Figure 8: BIM nD Process and Technology (Almutiri, 2016)

- **3D (The shared information model):**

It is BIM model visualization and simulation tool enables the team to visualize the building's details in physical environment which include graphical and non-

graphical information and sharing this information in a Common Data Environment (CDE) (Hardin, 2009; Grilo & Jardim-Goncalves, 2010; Sebastian, 2011; Azhar, 2011; Abbasnejad & Moud, 2013; Azhar, et al., 2015; McPartland, 2017).

- **4D (Construction sequencing):**

  It is a BIM model scheduling data tool with the dimension of time sequencing which enables the team to visually check the progress of the project and identify the critical activities resulting in enhancing enhance response appropriately to any risk (Dawood & Sikka, 2008; Kymmell, 2008; Eastman, et al., 2011; Abbasnejad & Moud, 2013; McPartland, 2017).

- **5D (Cost):**

  It is BIM model tool, enables the team to extract accurate cost information and provide a take-off of material quantities (Eastman, et al., 2011; Bryde, et al., 2013; Khosrowshahi & Arayici, 2012; Abbasnejad & Moud, 2013; McPartland, 2017).

- **6D BIM (Project lifecycle information (sustainability):**

  6D-BIM is a virtual model tool for the logistics of the construction site, to visualize the project sequential activities to prepare the safety analyses and safety plans. Additionally, it enables selection of the locations for material procurements, machinery and equipment suitable for the site (Hardin, 2009; Eastman, et al., 2011; Abbasnejad & Moud, 2013; McPartland, 2017).

- **7D facility management:**

  BIM 7D is used in processing object management in the stage of its operation. 7D allows extracting and storing data assets, such as the state of the object/component, technical specifications, required maintenance schedule and technical reviews, manuals or applicable warranty period. Such an approach to the facility management process not only improves the whole process but also improves the quality of services (Bim Estimate, 2016)

  Each tool of the abovementioned used in one or more of BIM applications as illustrated in Figure (9).

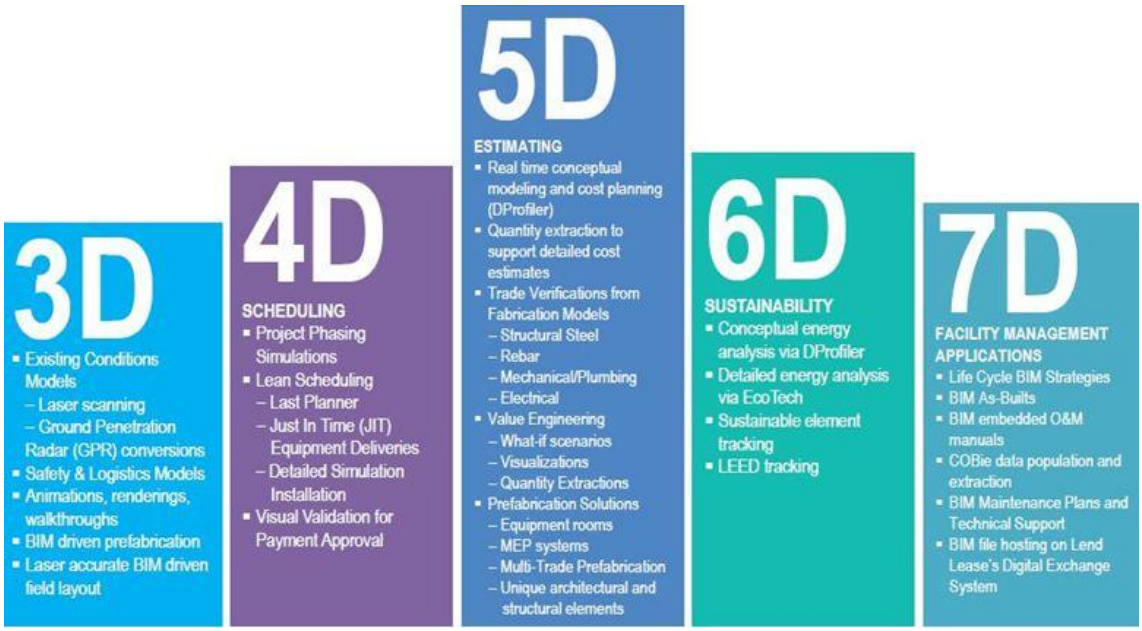

Figure 9: BIM Dimensions applications **(BIMtalk, 2012)**

2.2.5 BIM Maturity:

BIM has been categorized into various levels and while continuing increasing BIM adoption and implementation the movement from one level to another is referred to as 'BIM Maturity'. (Barnes & Davies, 2014)

BIM maturity levels can be summarized as follows:

Level 0: unmanaged CAD in 2D, with paper or electronic data exchange. Thus, this is not BIM and uses 2D CAD files for design and production information (Brewer, et al., 2012; Porwal & Hewage, 2013; Eadie, et al., 2013; Abbasnejad & Moud, 2013; Barnes & Davies, 2014). This level produces 25% increased cost through waste and rework (Barnes & Davies, 2014)

Level 1: Managed CAD in 2D or 3D with a collaboration tool providing common data environment. This level can be considered the first step to true BIM this may include 2D information and 3D information such as visualizations or concept development models. It can be described as 'Lonely BIM' as models are not shared between project team members (Brewer, et al., 2012; Porwal & Hewage, 2013; Eadie, et al., 2013; Abbasnejad & Moud, 2013; Barnes & Davies, 2014)

Level 2 (collaborative BIM environment): Managed 3D via implementation of BIM and deployment of BIM tools such as 3D, 4D, and 5D. This level completed in 2016 in the UK and any organization not complying with the level 2 requirements, the UK government decided not to include them in forthcoming government contracts. (Brewer, et al., 2012; Porwal & Hewage, 2013; Eadie, et al., 2013; Abbasnejad & Moud, 2013; Barnes & Davies, 2014).(Barnes & Davies, 2014) argued that this level provides waste reduction by 50%

Level 3: Full open process and data integration using all BIM tools and exploiting all BIM benefits, here BIM is considered to be fully integrated with the entire construction process. This level is empowered by “web services”, is usually compliant with emerging Industry Foundation Class (IFC) standards, and BIM will utilize 4D construction sequencing, 5D cost information and 6D project lifecycle management information. (Brewer, et al., 2012; Porwal & Hewage, 2013; Eadie, et al., 2013; Abbasnejad & Moud, 2013; Barnes & Davies, 2014). (Barnes & Davies, 2014) argued that this level provides increasing profit by 2% through a collaborative process.

Level 4: introduces the concepts of improved social outcomes and wellbeing (Barnes & Davies, 2014; SINGHAL, 2017).

Currently, in developing countries majority of BIM usage is at level 0 or level 1 and bridge between level 1 and 3 is getting wider (Gerges, M, et al., 2017). The AEC industry in a crucial need to upgrade to Level 2 to see the significant advantages of BIM and get out of 'Lonely BIM' (SINGHAL, 2017). In the UK, the Department of Business Innovations and Skills (BIS) has a significant effort in developing their BIM roadmap as illustrated in Figure (10). Their roadmap has helped to classify the maturity level of each UK companies and outline what they need to reach the government aim by 2016 and think about BIM future. Most of the UK construction companies are in level 1 and the best in class are experiencing significant benefits in level 2 (Porwal & Hewage, 2013).

BIM implementation is introduced as a three-phased approach separating as shown in Figure (11): an organization’s readiness to adopt (pre-implementation status); capability to perform (the willful implementation of BIM tools, workflows and protocols); and its performance maturity (post-implementation) (Succar & Kassem, 2015).

BIM maturity is the gradual and continual improvement in quality, repeatability, and predictability within available capabilities. BIM maturity is expressed as maturity levels (or performance improvement milestones) that organizations, teams and whole markets aspire to. There are five maturity levels: [a] Ad-hoc or low maturity; [b] Defined or medium-low maturity; [c] Managed or medium maturity; [d] Integrated or medium-high maturity; and [e] Optimized or high maturity (Succar, 2010).

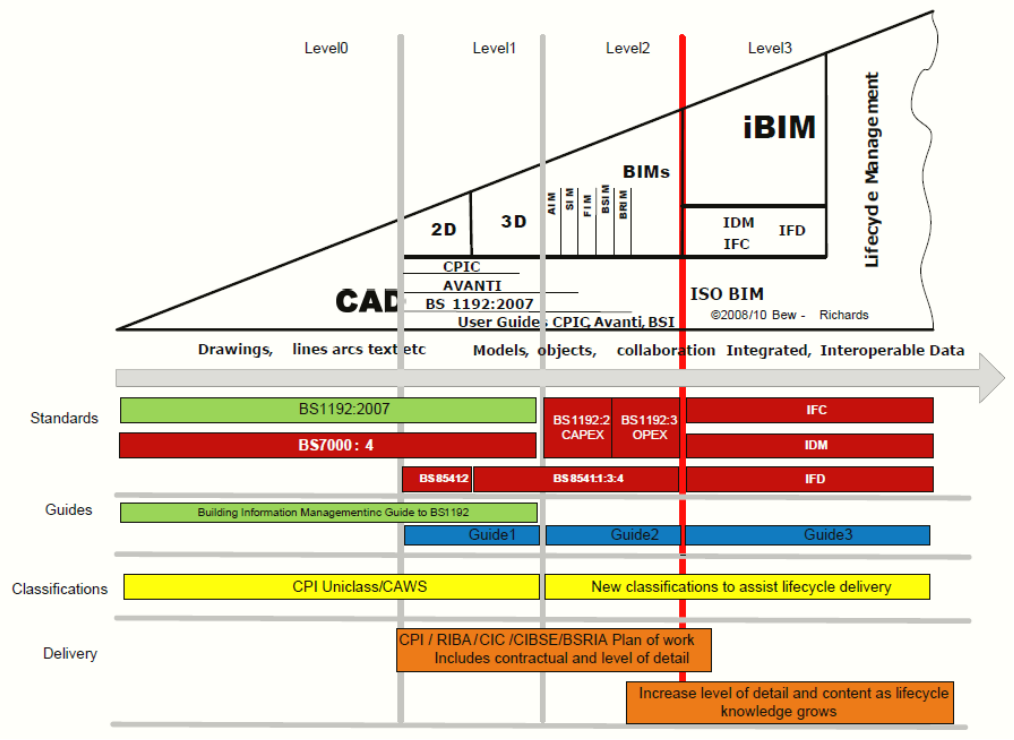

Figure 10: BIM maturity levels in the UK (BIS, 2011)

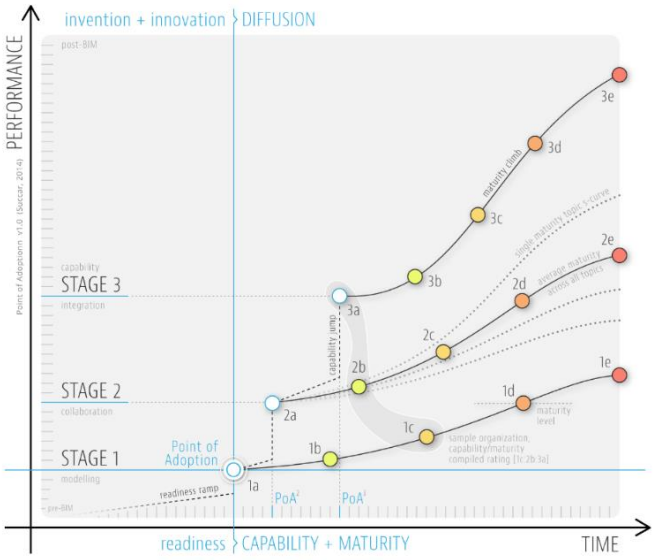

Figure 11: Point of Adoption model (Succar & Kassem, 2015)

Diffusion areas model, as shown in Figure (12), clarifies how BIM field types (technology, process, and policy) interact with BIM capability stages (modeling, collaboration and integration) to generate nine areas for targeted BIM diffusion analysis and BIM diffusion planning.

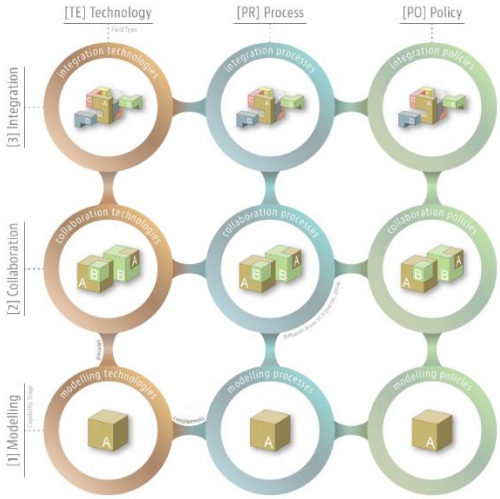

Figure 12: Diffusion Areas Model (Succar & Kassem, 2015)

2.2.6 How BIM works

The main essential duty of BIM is to have a central database for all the project parties seeking an integrated process through the AEC project lifecycle with an easy access enhancing making a significant decision, design and improving facility management (Almutiri, 2016).

BIM incorporates a methodology based on the notion of collaboration between stakeholders using ICT to exchange valuable information throughout the lifecycle (Figure 13). Such collaboration is seen as the answer to the fragmentation that exists within the building industry, which has caused various inefficiencies. Although BIM is not the salvation of the construction industry, much effort has gone into addressing those issues that have remained unattended for far too long (Jordani, 2008).

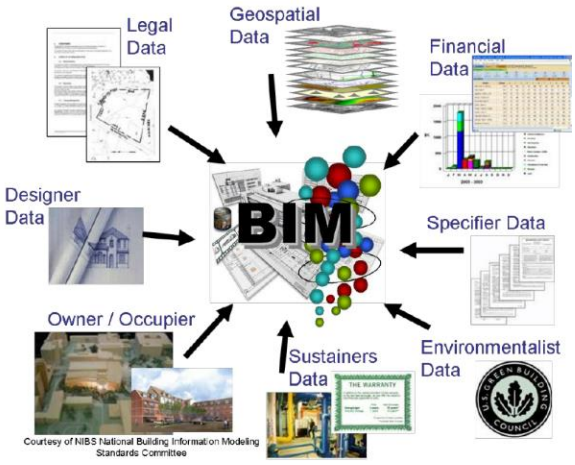

Figure 13: Communication, collaboration, and Visualization with BIM model (Jordani, 2008)

(Spehar, 2016) suggested that there are four steps for managing BIM projects:

1- Develop an engaged team

To deliver a successful project, the project, design and BIM management teams should be engaged as evidenced in Figure (14).

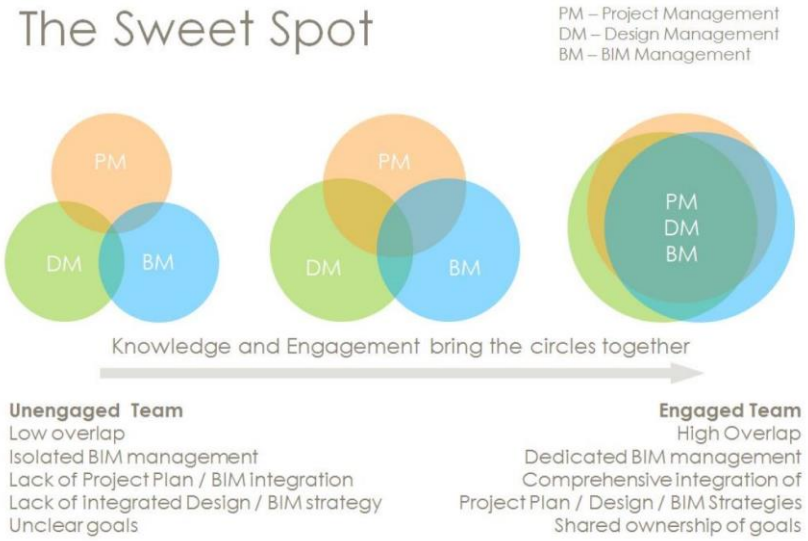

Figure 14: Develop an engaged team (Spehar, 2016)

2. **Tasks assignment**

Different tools were developed for managing various BIM task assignments from building models to managing data and creating drawings as a figure (15) illustrates.

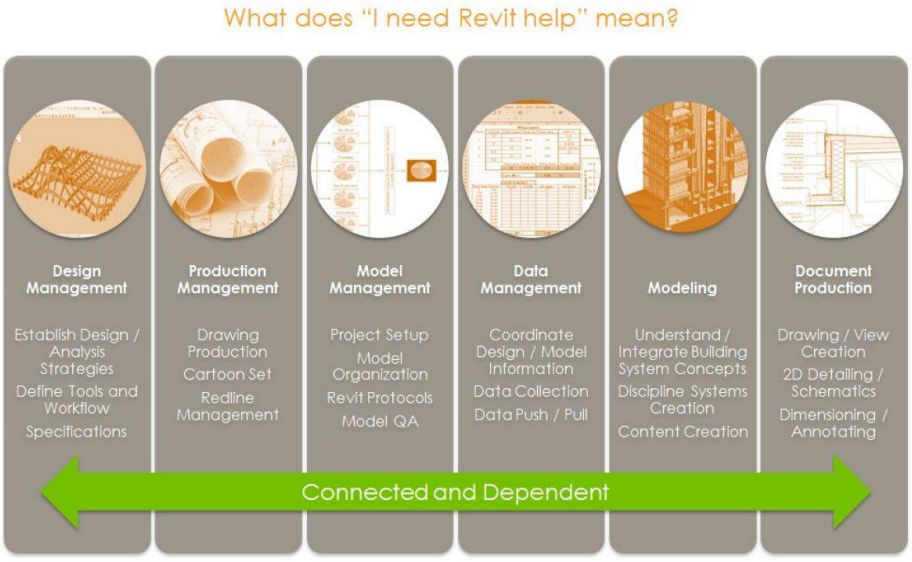

Figure 15: Tasks assignment (Spehar, 2016)

3. **Enhance Collaboration:**

The project manager should encourage collaboration between both design and project managers within the modelling team (Spehar, 2016).

4. **The BIM execution plan:**

A BIM execution plan (BEP) has to be a crucial part of the overall project plan to act as a resource for all stakeholders and to help the project manager to handle all changes in the process. Figure 16 explains that BEP requires inputs from all project, design and BIM managers (Spehar, 2016).

Figure 16: BIM execution plan (Spehar, 2016)

2.2.7 BIM applications:

BIM was suggested as a tool that will support the pre-design phase (Ham, et al., 2008). (Forbes & Ahmed, 2011) argued that BIM can be used for visualization interference and collision detection, construction sequencing, and conflict, cost estimating, fabrication/shop drawings, automated fabrication, code reviews, data analysis, facilities management. Moreover, (Arayici, et al., 2012; Memon, et al., 2014; Autodesk Design Academy, 2017) confirmed that BIM models used to support construction planning, constructability and analysis, cost and quantity feedback, construction techniques, fabrication, and facilities management. enterprise resource planning (Charles, 2017), Virtual Reality (VR) (Advenser, 2016), facility maintenance (Selezan & Mao, 2016), project management (Realcomm Staff Writer, 2011), Augmented Reality (AR) for interactive architectural visualization (Wang, et al., 2014), construction Management Education (Abbas, et al., 2016).

(Sacks, et al., 2010) provided a detailed description of the uses of BIM in construction. This includes visualization of form, collaboration in design and construction, Mechanical Electrical Plumbing (MEP), clash detection, and the rapid generation and evaluation of construction drawings, while (Hannele, et al., 2014) emphasized that the first use of BIM should be in the design and planning phase of the construction project. During the planning phase, different professional groups use BIM in architectural design, HPAC (heating, plumbing, and air-conditioning), electricity planning and structural design. (Succar, 2009) argued that the most “mature” application of BIM is seen to involve collaboratively created, shared, and maintained models across the project lifecycle. BIM can be implemented in various tendering routes in order to improve the overall process (Elbeltagi & Dawood, 2011)(Bolpagni, 2013) (Ciribini, et al., 2015). Many governments such as the UK, USA (Wong, et al., 2009), and Australia (Building SMART, 2012) have set implementations strategies for the use of BIM on construction projects. Figure (17), illustrates BIM applications through project life cycle.

Figure 17: BIM applications (Bim Dimension, 2013)

- **Clash detection**:

It is a 3D visualization application that can detect any clashes or undesirable interferences between the project elements, especially when there are several inputs of BIM models from different design teams i.e. Architect, structural, sustainable and MEP designers to be unified in a single model (Kunz & Gilligan, 2007; Sebastian, 2011; Eadie, et al., 2013; Omar, 2015; Saleh, 2015).

- **Project planning and construction monitoring:**

It is an application based on a 4D tool that accurately visualizes and simulates the construction sequences. This also enables the client and contractor to monitor the construction activities and automatically compare the actual progress against the planned to find out where and why the delay occurs (Grilo & Jardim-Goncalves, 2010; Azhar, 2011; Eastman, et al., 2011).

- **Cost estimating:**

It is an application depends on 5D BIM tool to estimate the cost in a very short time with great reliable accuracy at any time of the project, to enable decision makers to take the appropriate decisions on time (Sebastian, 2011; Jernigan, 2014; Love, et al., 2014; Harrison & Thurnell, 2014).

- **Material take-off:**

It is an application that depends on a 5D tool to determine the precise material quantities (material take-off) and correlates placing orders for the materials with the delivery dates based on site needs. The accuracy of the 5D take-off estimates is highly reliable and can be conducted at any time of the project, this application contributes to avoiding material waste and fosters lean construction principle (Azhar, et al., 2015; Moreno, et al., 2013).

- **Sustainability analysis**:

BIM application tools such as 3D simulation and visualization are used to determine and evaluate the building future performance with a reliable accuracy. BIM simulation tool demonstrates the best orientation for the building to save the energy based on the sun direction, sound levels, wind speed and direction, light affection, spatial performance and the building envelope (Azhar, et al., 2015).In addition to, the ability of BIM to compare and simulate the sustainability measures in terms of internal energy performance such as MEP details. Different options according to the specifications that are uploaded to BIM software, all these comparisons are implemented in no time to select the best option that is appropriate for the building throughout its life-cycle in terms of energy saving and sustainable principles (Kymmell, 2008; Azhar, et al., 2015; Nawari, 2012).

- **Data transfer to facility management:**

3D model is a platform that is very rich with detailed information. This information includes the infinitesimal details for each and every item in the building with a unique barcode that carries a unique name, installation data, and the required maintenance date including manufacturer and suppliers contact details (Newton, 2004; Kymmell, 2008; Jordani, 2010; Eastman, et al., 2011; Moreno, et al., 2013). (Sabol, 2008) reported that BIM was used to aid facility management on the Sydney Opera House.

- **Site logistics and safety management:**

It is an application based on 6D BIM tool that visualizes the arrangements required for the site logistics i.e. the best locations for cranes, store yards, and site offices and so forth. In addition to its ability to visualize the project activities to precisely evaluate the safety hazards to be ready for the appropriate responses. 6D tool enables health and safety specialists to train the staff and employees for the best practices based on the visualization and simulations of the project activities offered by BIM model (Hardin, 2009; Zhang & Hu, 2011; Eastman, et al., 2011; Sebastian, 2011; Barlish & Sullivan, 2012; Bhat & Gowda, 2013).figure (19) show how can BIM use in Site logistics.

- **Build-in code and specifications:**

BIM software models are developed to include the required codes, standards and project specifications which can run automatic checking to verify the compliance with the uploaded codes, standards and project specifications to alert and notify any deviation in the drawings and submittals (Hardin, 2009; Eastman, et al., 2011).

Figure 18: Use of 4D BIM for optimizing construction site logistics at HOAR Construction Company (Sattineni & Macdonald, 2014)

(Kunz & Gilligan, 2007; Itech, 2017) concluded that BIM can be used in pre-construction, construction, disaster management and life-cycle management. Table (2), summarized the use of BIM through the project life cycle. Figure (19), shows that BIM can be used in various project phases.

Table 2: BIM applications in a construction project (Furneaux & Kivvits, 2008; Latiffi, et al., 2013)

Phase	Stage	Uses of BIM
Pre-construction	Existing conditions modeling	- Enhances accuracy of existing conditions documentation
	Planning	- Identifies schedule sequencing or phasing issues
	Design	- Facilitates better communication and faster design decision. - Perform clash detection and clash analysis. - Increases design effectiveness.
	Scheduling	- Enables project manager and contractor to see construction work sequence, equipment, materials and track progress against logistics and timelines established.
	Estimate	- Enables generation of takeoffs, counts, and measurements directly from a 3-Dimensional (3D) project model.
	Site analysis	- Decreases costs of utility demand and demolition.
Construction	Construction	- Enables demonstration of the construction process, including access and exit roads, traffic flows, site materials and machinery. - Provides better tracking of cost control and cash flow. - Enables tracking of work in real time, faster flow of resources and better site management.
Post construction	Operation / Facilities management	- Keeps track of built asset. - Manages facilities proactively. - Enables scheduled maintenance and provides a review of maintenance history.

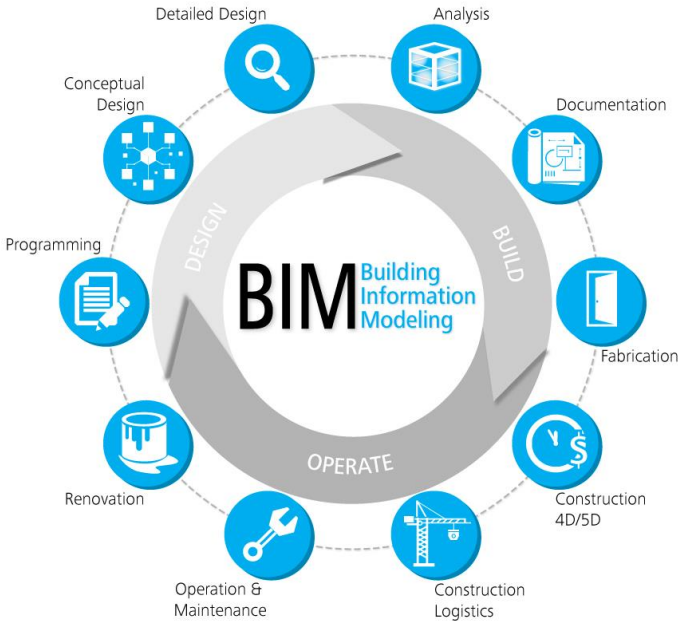

Figure 19: BIM applications through project lifecycle (Deshmukh, 2016)

2.2.8 Integration with BIM

In last two decades, BIM proved its competencies to integrate with various concepts and new knowledge which resulted in enhancing its efficiency and performance and provide new alternative solutions and outcomes. BIM can be integrated with Computer-aided facility management (CAFM) (Service Works

Group, 2015), health and safety (Ganah & John, 2015). Some other suggested integrations with BIM as following:

Integrated Project Delivery (IPD):

The implementation of BIM supports the concept of Integrated Project Delivery (IPD) which is a novel project delivery approach to integrate people, systems, business structures and practices into a collaborative process to reduce waste (of time, resources, money) and optimise efficiency through all phases of the project lifecycle (Glick & Guggemos, 2009).

Geography information system (GIS):

The integration of 3D BIM model with GIS can provide quick and accurate identification of the construction, semantically rich models, and get the benefits from both systems to help documenting and analyzing cultural heritage sites. (El Meouche, et al., 2013; Baik, et al., 2015; Zlatanova, 2016).

Green Building:

Construction is a major consumer of nonrenewable resources. In addition, it is responsible for a huge portion of waste production and CO2 emissions (Bakhoum & Brown, 2011). Saudi Arabia Green Building Rating System (SAGRS) would be integrated into a framework that is dedicated for selecting optimum sustainable building materials that were developed, expanding the features of BIM technology (Marzouk, et al., 2014). Resources limitations and serious environmental impacts lead to increase the importance of adoption of more sustainable lifestyle (Ljungberg, 2007). The expanded features of BIM technology integrate with especially designed green building rating system for Saudi Arabia (Marzouk, et al., 2014; Amor, et al., 214).

Lean construction:

(Brown, 2017; Zewein, 2017) argued that “Combining lean construction thinking (in the shape of last planner approaches) and BIM on construction projects can enhance big reductions on time, cost, waste and stress, and promote profits, capability, staff wellbeing, and reputation”

Health and safety:

BIM can be used in worker safety training and education, design for safety, safety planning (job hazard analysis and pre-task planning), accident investigation, and facility and maintenance phase safety (Rajendran & Clarke, 2011; Alomari, et al., 2017; Mordue, et al., 2017).

2.2.9 BIM Status Globally and future trends

(Jung & Lee, 2015) brought light to BIM status on the level of the six continents which are set forth below:

- North America comes at the first place ahead of other continents in each approach.
- Oceania and Europe are ranked secondly, but get distinguished in the design phase.
- Asia is identified on the same line with advanced continents in BIM adoption despite being ranked the 5th in the engagement level.
- Middle East/Africa come the third in the BIM adoption, still stuck in the beginner phase.
- At last, South America is the lowest.

Many developed countries such as (USA, Canada, UK, Germany France Finland, Singapore, Norway, Denmark, South Korea Australia, Hong Kong, Netherlands) mandated BIM in their public AEC industry projects motivated by its benefits, while others adopted strategic plans for mandating BIM (Mihindu & Arayici, 2008; Takim, et al., 2013; Zeiss, 2013; Lee, et al., 2014). However, almost all developing countries did not mandate BIM yet, but they are on the road too. In GCC region, in 2014, Dubai municipality Mandate BIM in their large projects. BIM market is currently worth around $2.6bn (Construction Work team, 2014).

Countries of the advanced world have been preceding in BIM adoption rate which serves experience level of users, North America has remarkable increase from 2007 to 2012 steeply rising from 28% up to 71 %, also, South Korea and Oceania are on the same path (McGrawHillConstruction, 2014).

UK has also achieved a steady increase in adoption from 31.0% in 2010 when UK announced BIM requirements to 39% in 2012 (National Building Specification, 2014) and 54.0% in 2013 then actually mandated BIM in public sector in 2016 to level 2 (Porwal & Hewage, 2013). Onwards till the kingdom become the current world leader in BIM adoption speed (The National BIM Survey, 2014; McGrawHillConstruction, 2014). Although, Finland was ahead in early researching and adopting BIM (Kiviniemi, 2015).

In South Asia, Singapore shows rapid adoption rate, since 1997 when the country started promoting BIM, in 2011 the country issued a nationwide roadmap for BIM implementation so that BIM started to be used for various aspects in construction such as building plan approvals and fire safety certifications. From 2015 onwards, the government mandated the use of BIM in public sector projects for new building projects over 5000 m^2. While BIM has been globally expanding in a colossal

speed, a significant difference in experience appeared among construction companies according to various regional business benefits (Chan, 2014).

A wide concern has been paid from researchers to market-scale of BIM and diffusion worldwide. Several studies covers multiple countries such as those for US (Giligan & Kunz, 2007; Liu, et al., 2010), UK (Khosrowshahi & Arayici, 2012),Australia (Gu & London, 2010), China (Cao, et al., 2014), Finland (Lehtinen, 2010), Iceland (Kjartansdóttir, 2011), India (Luthra, 2010), South Africa (Froise & Shakantu, 2014), Sweden (Samuelson & Björk, 2013), Taiwan (Mom, et al., 2011), and multiple markets (Smith, 2014; Panuwatwanich & Peansupap, 2013; Wong, et al., 2010; Bin Zakaria, et al., 2013).

Several researchers made to cover Western Europe such as Germany, France, Austria, Finland, Denmark, Norway, and Sweden revealed that a little over one-third of the industry (36%) has adopted BIM by 2010 (Construction, M.H, 2010).

In some regions, BIM is getting established by contractors, for instance, Japan, South Korea, and Austria/New Zealand represent the next tier of maturity. In East Asia, for example, South Korea, a 65% BIM adoption rate in 2012 was represented by contractors (Chan, 2014). Figure (20), demonstrated that the countries adopted BIM lately show a slow limited spread of BIM (Mehran, 2016). In the Middle East, only 10% of construction projects are using BIM (CW Staff, 2014).

Since AEC industry players in both UK and USA have well-recognized merits of BIM, both countries were the earlier to mandate BIM in high profile and large projects, such as London 2012 Olympics, Veldodrome cycle track and the 48 floor Leaden hall building “The Cheesegrater” which is one of the London’s tallest buildings (Bryde, et al., 2013). BIM also utilized for complex projects such as EMP museum at Seattle Center, Washington national park, Walt Disney Concert Hall (Chien, et al., 2014).

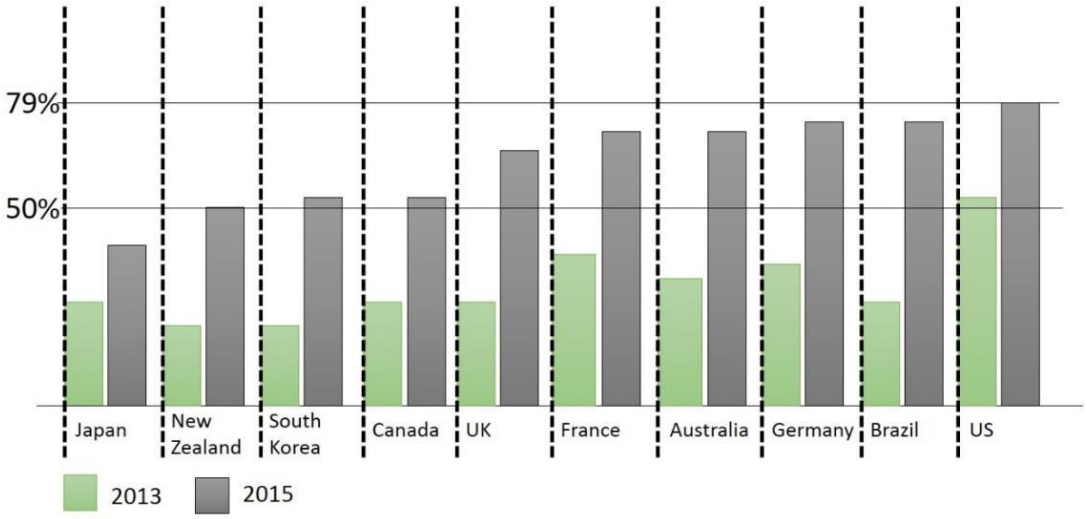

Figure 20: the construction companies in ten developed countries have highly adopted BIM within their system (McGrawHillConstruction, 2014)

2.2.9.1.1 BIM in KSA

However, BIM is rarely used in KSA (Construction Work team, 2014; Almutiri, 2016), recently, construction companies in KSA: local and international, are seeking BIM expertise to work in KSA (Glass Door, 2017; LinkedIn, 2017).

The adoption of BIM has seen a slow but gradual upward trend within SA in recent years (Alhumayn, et al., 2017).

In 2014, Anwar Al Qasmi from Tekla as software provider reported that they participate in prominent projects in SA using BIM such as the Capital Market Authority Headquarters, King Abdullah Financial District, and the King Abdulaziz Center for World Culture, 11 world-class stadiums, and King Abdullah Sports City complex in Jeddah, (Saudi Gazette, 2014; Construction Work team, 2014).

2.2.10 BIM Tools

Recently, several BIM tools used to enhance the BIM concept including Revit Architecture, Revit Structural, Revit MEP, Navisworks and Cost-X (Latiffi, et al., 2013; Chan, 2014; Rodriguez, 2014), Micro-station and ArchiCAD (Chan, 2014; Rodriguez, 2014), and Tekla & Solibri' (Rodriguez, 2014).

In the last 5 years, the most BIM tools used in the Middle East was Revit followed by AutoCAD (Gerges, M, et al., 2017). Other software and BIM technologies such as Navisworks was identified to be used essentially for construction schedule simulation, While Solibri, StaadPro, Civil 3D, and Robot structure were scarily used. Even though on-site professionals still use 2D drawings for erection and placement (Gerges, M, et al., 2017).

Moreover, the Autodesk software "Revit Architecture" has been used widely within universities in the United States to teach undergraduate architecture programme

(Alshanbari, et al., 2014; Aly, 2014; Joannides, et al., 2012; Rodriguez, 2014; Sabongi & Arch, 2009). More than 70% of universities use Revit Architecture and the other 30% use other software including ArchiCAD and Bentley (Joannides, et al., 2012). In the UK, more than 79% adopted Revit (Architecture – Structure – MEP), and 45.6% used Navisworks followed by 42.1% who used Sketch Up (Underwood, et al., 2015). Figure (21), shows the most used of BIM tools. Table (3), illustrate the software used to every model.

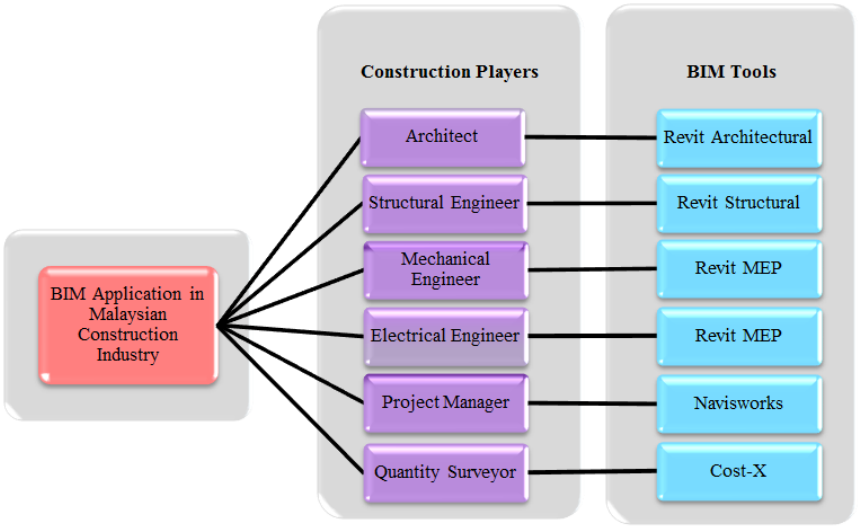

Figure 21: BIM tools suggested by PWD (Latiffi, et al., 2013)

Table 3: BIM Software (Computer Integrated Construction Research Program (CICRP), 2012; Olugboyega, 2017)

Model	Software
Architectural model	. Architectural Desktop, Bentley Architecture, V8, Vectorworks, Revit Architecture
Structural model	X Steel, SDS/2, QuickPen, CADPIPE, SOFTEK, Revit Structure, CSC, Tekla Structure, ETABS, RISA, SoFiSTiK, Bentley Structure, Orion
Mechanical, Electrical and Plumbing (MEP) model	Revit MEP, Bentley Mechanical, Hevacomp Mechanical designer, 3D pipe designer, AutoCAD MEP, CADPIPE electrical, HVAC System design, CADMECH, CAMduct, Multi-pipe, Bentley Electrical, Autopipe
Schedule and time model	MS Project, Primavera, Bentley Schedule Simulator, Jet-Stream timeliner, Ebuilder, Newforma
Resources and cost model	MS Project, IES, Autodesk QTO, Cost X, Ideate BIM link, Sefaira, Planswift, Timberline, Vico Cost Planner, Innovaya Visual Estimating
Construction and site utilization	model Unity 3D game engine, AutoCAD Civil 3D, Power Civil, InRoads Site, Hevacomp Simulator, Bentley Simulator
Operation and maintenance model	CMMS, IBM Maximo, Bentley facilities, Autodesk FM desktop, One Tool, Geospatial and facilities
Sustainability model	IESVE, Autodesk Green Building Studio

2.2.11 Roles and responsibilities of BIM Specialist

BIM Modeler

The Functions of a BIM Modeler is to create and develop 3D BIM models and to extract 2D documentation from Models (General Services Administration, 2009). BIM Modeler can also be called BIM Operator (Kymmell, 2008).

BIM Analyst

The function of the *BIM Analyst* is to perform analysis and simulations based on the BIM model (General Services Administration, 2009).

BIM Application Developer or BIM Software Developer

A *BIM Application/Software Developer* is a specialist that develops and customizes the *software* to support integration and the BIM process (Abdulkader, 2013).

Modelling Specialist

Modelling Specialists are IT professionals who contribute, along with experts in different areas of the AEC/FM industry, to the IFC standard, from initial requirements to the final characteristics of a software product (Barison & Santos, 2010; Abdulkader, 2013).

BIM Facilitator

The function of a *BIM Facilitator* is to assist other professionals, not yet skilled in operating BIM software, in visualizing the model information. He usually works with who is going to physically construct the building, assisting the engineer's work to communicate with foremen or contractors (Kymmell, 2008; General Services Administration, 2009; Barison & Santos, 2010; Abdulkader, 2013).

BIM Consultant

Large and medium-sized companies that have adopted or are going to adopt BIM, and do not have an experienced expert to be part of the project team, can hire a BIM consultant to guide project designers, developers, and builders in the BIM implementation. There may be three types of BIM Consultants: Strategic Consultant, Functional Consultant and Operational Consultant (Barison & Santos, 2010).

BIM Researcher

BIM Researcher is the expert who works in universities, research institutes or governmental organizations, teaching, coordinating and developing researches

on BIM. They will be leaders in the creation of new knowledge to benefit the industry, the community and the environment (Barison & Santos, 2010).

BIM manager

BIM manager should be responsible for coordination, control, development and updating BIM model (Gu & London, 2010; Sebastian, 2011).He/she should possess Information and Communication Technology (ICT) experience, construction experience, excellent experience of BIM software and communication management skills because he/she is dealing with the BIM system and project actors (InPro, 2009). He/she receives BIM models in various software format from different teams and converts it to a single master BIM model, running the clash detection for these models, delivering the electronic drawings and specifications to the contractor for implementation, preparing the as-built BIM files to be used by FM (Hardin, 2009; Eastman, et al., 2011; Sebastian, 2011; Brewer, et al., 2012; New Zealand, B.I.M, 2014).

There are three Specializations of BIM manager: the first project model manager, modeling manager or model manager the second BIM manager at design firms or chief BIM-officer And the third one is BIM manager at general construction and subcontractor firms - BIM construction officer (Barison & Santos, 2010).

(Joseph, 2011) Pointed out, in Figure (22), that the placement of corporate staff is the most critical to the success of BIM Implementation across the organization that includes the cultural and human resource shift. BIM corporate staff are responsible for the education, deployment, and standards of a solid BIM strategy. Their skills are in place to expand the services the firm offers and will touch all areas in a firm including overheads, marketing material and billable project aspects of the business.

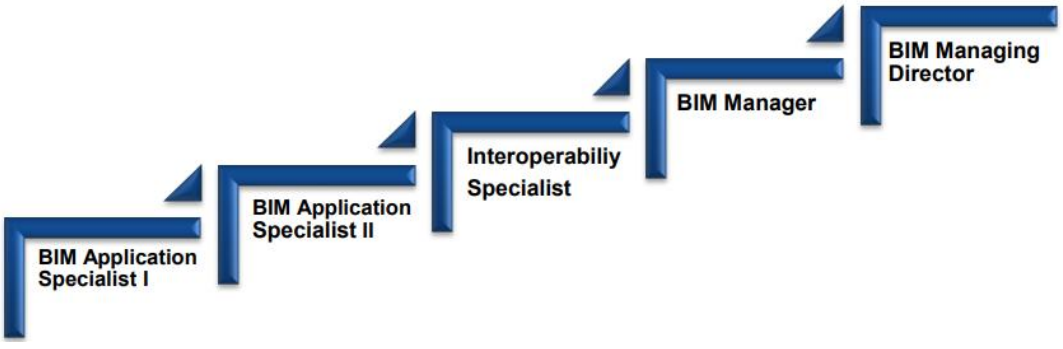

Figure 22: BIM Corporate Support Team Ladder (Joseph, 2011)

2.2.12 Organizations can use BIM

Adopting a multidisciplinary BIM approach can lead to major benefits for architecture firms and construction companies (Coates, et al., 2010; Arayici, et al., 2012).

2.16 The benefits of BIM

Like other industry reaping the benefits of information and communication technology (ICT), AEC industry can gain features from ICT (Latiffi, et al., 2013). The adoption of new technology has many common benefits (Gudgel, 2008). BIM is rapidly growing as the latest advanced technology in the AEC industry. BIM has modified the way construction projects are designed, constructed and operated (Azhar, et al., 2015). Features of BIM could be predestined in different ways depending on how far users have experienced either beginners or experts (McGraw-Hill, 2009). Several researchers considered the benefits of BIM as following:

(Latiffi, et al., 2013) reported that BIM can overcome construction project problems such as delay, construction cost overrun and the clash of design by different specialties (Architecture, structure, MEP and etc.). Due to the powerful data-based modeling, visualization, analysis and simulation capabilities of BIM, it has the potential to significantly impact the Saudi construction industry by dealing with issues pertaining to estimating, scheduling and design coordination (Almutiri, 2016). Moreover (Succar, 2009) claimed that the main benefits of implementing BIM is the visual coordination of the building systems such as MEP systems and it also identifies the possible conflicts between these. By detecting the conflicts, problems can be resolved before actual construction which in turn saving project time and cost (Building SMART, 2010; Institute for BIM in Canada (IBC), 2011).

Furthermore, according to Tekla BIMsight solution, BIM enables architects, engineers, and project managers to deliver projects on time and within budget, providing reliable feasibility studies for the design, building, and operating phases. (Saudi Gazette, 2014). Additionally, (Building SMART, 2012) argued that BIM enhances quality control, productivity, and emphasise design errors reduction.

Whereas, (Harrison & Thurnell, 2014) concluded the benefits of BIM as: (1) Enhances decision making,(2) Mitigates inaccurate interpretation, (3) Facilitates efficient estimates, (4) Enhances efficient cost plans, (5) Enables efficient scheduling quantities, (6) Automatic quantities generation save time, (7) Expedite and easily Design changes, (8) Automatic quantities generation eliminate human error, (9) Enhances the accuracy of estimates, (10) Improves communication among the project team ,(11) Facilitates access to the data base, (12) Provides early construction schedule details, (13) Enhances the competitive

advantages,(14) Improves coordination through integration of specifications, and (15) Clash detection.

However, (Salla, 2014) summarized the top fifteen benefits gained from using BIM in its order as: (1) Reduce errors and omissions in the design phase, (2) Improve collaboration with owner/design firms during the construction phase, (3) Enhances organizational image, (4) Reduce rework, (5) Lowering construction cost, (6) Better cost control and predictability, (7) Reducing the overall project duration, (8) Marketing new business, (9) Offering new services, (10) Increasing profits, (11) Maintaining repeat business, (12) Reducing cycle time of workflows, (13) Faster client approval cycles, (14) Improved safety, (15) Faster regulatory approval cycles.

Based on an extensive literature review. Table (4), summarizes the most recognized benefits of BIM and the beneficiary party.

Client: C, Architect/Engineer: A/E, Contractor/Subcontractor: C/SC, Supplier: S Other Stakeholders: OS, Facility Management: FM

Table 4: Literature review for Perceived benefits of BIM

No.	Benefits of BIM	Stakeholders						Authors
		C	A/E	C/SC	S	OS	FM	
1	**Time savings** (duration improvements, reduces the time spent on project documentation and communication, and comparing between different options in a very short time.)	√	√	√	×	√	×	(Howard & Björk, 2008; Hardin, 2009; Sebastian, 2011; Barlish & Sullivan, 2012; Construction, M.H, 2012; Bryde, et al., 2013; Chan, 2014; Doumbouya, et al., 2016; Matarneh & Hamed, 2017)
2	**The cost reduction** (lowers the project whole cost, design and construction costs, reduced communication cost)	√	√	√	×	√	×	(Howard & Björk, 2008; Hardin, 2009; Sebastian, 2011; Barlish & Sullivan, 2012; Construction, M.H, 2012; Bryde, et al., 2013; Chan, 2014; Doumbouya, et al., 2016; Matarneh & Hamed, 2017)
3	Improved Budget and Cost **Estimating** Capabilities	√	√	√	×	√	×	(Azhar, 2011; Elbeltagi & Dawood, 2011; Ma, et al., 2011; Construction, M.H, 2012; Chan, 2014)
4	**Improving the quality**(Reduced Rework, reduction of design errors, Better design)	√	√	√	√	√	√	(Nour, 2007; Yan & Demian, 2008; Liu, et al., 2010; Azhar, 2011; Arayici, et al., 2012; Construction, M.H, 2012; McGrawHillConstruction, 2014; Autodesk, 2015; Doumbouya, et al., 2016; Gerges, M, et al., 2017)

5	**Quick and right decisions** based on authenticated data	√	√	√	√	√	√	(Kymmell, 2008; Jernigan, 2014; Harrison & Thurnell, 2014; Love, et al., 2014)
6	**Clash detection**(reduced coordination problems, eliminating the risk of duplication, checks design non-conformities during pre-construction stage, resolve physical conflicts between different disciplines, and Integrated work progress)	√	√	√	√	√	√	(McCartney, 2010; Liu, et al., 2010; Lu & Korman, 2010; Forgues, et al., 2011; Construction, M.H, 2012; Chan, 2014; Autodesk, 2015; Doumbouya, et al., 2016; Matarneh & Hamed, 2017; Gerges, M, et al., 2017)
7	**Improves visualization**(Simulation, representation of the parts of a building in an integrated data environment, eliminating the risk of misinterpretation of design, and capture reality)	√	√	√	√	√	√	(Innovation, C.C., 2007; McCartney, 2010; Sacks, et al., 2010; Arayici, et al., 2011; Azhar, 2011; Chan, 2014; Harrison & Thurnell, 2014; Autodesk, 2015; Advenser, 2016; Gerges, M, et al., 2017)
8	**Enhance collaboration & communication** between all parties (Minimizing conflicts, Simultaneous work by multiple disciplines, Improved Coordination, Teamwork Integration)	√	√	√	√	√	√	(Anumba, et al., 2008; McCartney, 2010; Grilo & Jardim-Goncalves, 2010; Roh, et al., 2011; Shen, et al., 2012; Autodesk, 2015; Matarneh & Hamed, 2017)
9	**Maintain Control** through the project life cycle	√	√	√	√	√	√	(Lu & Korman, 2010; Arayici, et al., 2011; Azhar, 2011; Bryde, et al., 2013; Harrison & Thurnell, 2014; Autodesk, 2015; Matarneh & Hamed, 2017)
10	**Reduce risks**	√	√	√	√	√	√	(Ghayamghamian & Khanzade, 2008; Hardin, 2009; Eastman, et al., 2011; Barlish & Sullivan, 2012; Porwal & Hewage, 2013; Jernigan, 2014)
11	**Supporting construction and project management** (executive, communication, strategic planning, and site planning, risk, change, safety, value, and facility management,)	√	√	√	√	√	√	(Babič, et al., 2010; Grilo & Jardim-Goncalves, 2010; Sacks, et al., 2010; Zhou, et al., 2011; Realcomm Staff Writer, 2011; Latiffi, et al., 2013; Chan, 2014; Gerges, et al., 2016; Matarneh & Hamed, 2017)
12	**Error-free design**	√	√	√	√	√	√	(Samuelson & Björk, 2013; Omar, 2015; Dey, 2015; Tekla BIMsight, 2016)
13	**Reduced requests for information** (RFIs') (promote project understanding and eradicates any ambiguity)	√	√	√	√	√	√	(Arayici, et al., 2011; Azhar, et al., 2011; Abbasnejad & Moud, 2013)

14	**Client early involvement**	√	√	√	√	√	√	(Manning & Messner, 2008; Eastman, et al., 2011; Jernigan, 2014; Omar, 2015)
15	**Promotes the client and customer satisfactions**	√	√	√	√	√	√	(Yang & Peng, 2008; Karna, et al., 2009)
16	**Keep the stakeholders informed and satisfied**.	√	√	√	√	√	√	(Hardin, 2009; Liu, et al., 2010; Eastman, et al., 2011; Azhar, 2011; Elmualim & Gilder, 2014; Jernigan, 2014)
17	**Maximizing productivity**	√	√	√	√	√	√	(Kaner, et al., 2008; Liu, et al., 2010; Eastman, et al., 2011; Olatunji, 2011; Barlish & Sullivan, 2012; McGraw-Hill, 2012; Doumbouya, et al., 2016; Matarneh & Hamed, 2017)
18	**Lifecycle data**	√	√	√	√	√	√	(Glick & Guggemos, 2009; Popov, et al., 2010; Gecevska, et al., 2010; Azhar, 2011; Arayici, et al., 2012; Abbasnejad & Moud, 2013; Chan, 2014; Doumbouya, et al., 2016; Gerges, M, et al., 2017),
19	**Reduced Document Errors and omissions**	√	√	√	√	√	√	(McCartney, 2010; Eastman, et al., 2011; Arayici, et al., 2011; Construction, M.H, 2012; Moreno, et al., 2013; Autodesk, 2015)
20	**Minimizing Changes**(reduce or eliminate change orders)	√	√	√	√	√	×	(Barlish & Sullivan, 2012; Matarneh & Hamed, 2017)**.**
21	**Reduce accidents by Promoting safety plans**	√	×	√	×	√	×	(Zhang & Hu, 2011; Eastman, et al., 2011; Barlish & Sullivan, 2012; Moreno, et al., 2013)
22	**Enhance site logistics plans**	√	×	√	√	√	√	(Sebastian, 2011; Abbasnejad & Moud, 2013; Saleh, 2015)
23	**Enhance the lean construction principle and value engineering**	√	√	√	√	√	√	(Howard & Björk, 2008; Sebastian, 2011; Alwan, et al., 2015; Zewein, 2017; Khalil, 2017)
24	**Promotes the money value**	√	√	√	√	√	√	(Barrett, 2008; Elmualim & Gilder, 2014)
25	**increasing efficiency** (faster and more effective processes and method)	√	√	√	√	√	√	(Glick & Guggemos, 2009; Harrison & Thurnell, 2014; Doumbouya, et al., 2016; Matarneh & Hamed, 2017)
26	**Improve the building sustainability analyses**	√	√	√	√	√	√	(Azhar, et al., 2011; Eastman, et al., 2011; Porwal & Hewage, 2013; Eadie, et al., 2013; Doumbouya, et al., 2016)

27	**Creativity and innovative solutions**	√	√	√	√	√	√	(Yan & Demian, 2008; Popov, et al., 2010; Sacks, et al., 2010; Azhar, 2011; Chan, 2014)
28	**Automated assembly**	√	×	√	√	√	√	(Azhar, 2011; Arayici, et al., 2012; Milender White, 2016)
29	**Reduce Waste**(the elimination of wastes and value generation)	√	√	√	√	√	√	(Glick & Guggemos, 2009; Arayici, et al., 2011; Azhar, 2011; Eastman, et al., 2011; Omar & Dulaimi, 2014; Autodesk, 2015)
30	**Enhance Competitiveness** (Promotes the company's competitive advantages)	√	√	√	√	√	√	(Liu, et al., 2010; Sebastian, 2011; National Building Specification, 2014; Azhar, et al., 2015)
31	**Facility Management**	√	√	√	√	√	√	(Sabol, 2008; Omar, 2015)
32	**Facility Maintenance** (easy access to data for efficient O&M.)	√	√	√	√	√	√	(Carmona & Irwin, 2007; Kymmell, 2008; Arayici & Aouad, 2010; Azhar, 2011; Selezan & Mao, 2016)
33	**Reduced claim and law issues** (reduced litigation and insurance claims)	√	√	√	√	√	√	(Liu, et al., 2010; Construction, M.H, 2012)
34	**Improved Accuracy**	√	√	√	√	√	√	(Liu, et al., 2010)
35	**Increased Profits**	√	√	√	√	√	√	(Liu, et al., 2010; Construction, M.H, 2012)
36	**Helps procurement**	√	√	√	√	√	√	(Glick & Guggemos, 2009; Moreno, et al., 2013; Love, et al., 2014; Chan, 2014; Gerges, et al., 2016)
37	**Promotes the prefabrications** for better quality (reduce the inventory duration and order materials using Just In Time (JIT)).	√	x	√	√	√	√	(Elbeltagi & Dawood, 2011; Eastman, et al., 2011; Bryde, et al., 2013)
38	**Designers becoming more knowledgeable in the construction process.**	√	√	√	√	√	√	(McCartney, 2010)
39	**Maintain Repeat Business**	√	√	√	√	√	√	(Construction, M.H, 2012)
40	**Market New Business** (Offer New Services)	√	√	√	√	√	√	(Construction, M.H, 2012)
41	**Present Perfectly**	√	√	√	√	√	√	(Forgues, et al., 2011; Arayici, et al., 2012; Chan, 2014; Autodesk, 2015)
42	**More Owner Demand**	√	√	√	√	√	√	(Construction, M.H, 2012)
43	**Reduce human resource** (reduce the amount of staff in the long run, and Staff Recruitment and Retention)	√	√	√	√	√	√	(Yan & Demian, 2008; Glick & Guggemos, 2009; Construction, M.H, 2012; Chan, 2014)
44	**Dive into Detail**	√	√	√	√	√	√	(Autodesk, 2015)
45	**Quickly and easily Integrate new team member**	√	√	√	√	√	√	(Jernigan, 2014)

46	**Overcoming distance barriers.**	√	√	√	√	√	√	(Hardin, 2009; Eastman, et al., 2011)
47	**Promote the designers' capacity** and increases the competition	√	√	√	√	√	√	(Eastman, et al., 2011; Samuelson & Björk, 2013)
48	**Bridge the capacity gaps** with the international AEC professionals	√	√	√	√	√	√	(Eastman, et al., 2011)
49	**As-built drawings** (laser scanning for existing properties/services and (RFID) to automatically produce)	√	√	√	x	√	√	(Kymmell, 2008; Jernigan, 2014; Love, et al., 2014; Volk, et al., 2014)
52	**Computer-aided facility management** (CAFM)	√	√	√	√	√	√	(Service Works Group, 2015)
53	**Take it with you**; access to the model and project details from anywhere, on any device.	√	√	√	√	√	√	(Autodesk, 2015)
54	**Augmented reality** for interactive architectural visualization	√	√	√	√	√	√	(Wang, et al., 2014; Omar, 2015)
55	**GIS integrated with BIM**	√	√	√	×	√	×	(El Meouche, et al., 2013; Irizarry, et al., 2013; Mignard & Nicolle, 2014; Rafiee, et al., 2014; Baik, et al., 2015; Zlatanova, 2016)
56	**Health and Safety**	√	×	√	√	√	√	(Ganah & John, 2015)
57	**Improve energy saving and provide healthy environment** by integrated Green Building with BIM	√	√	√	√	√	√	(Amor, et al., 214)
58	**Improve Enterprise Resource** Planning by integrated with BIM	√	√	√	√	√	√	(Charles, 2017)
59	**Conformity with specifications, standards and codes**	√	√	√	√	√	√	(Howard & Björk, 2008; Hardin, 2009; Eastman, et al., 2011; Sebastian, 2011)

Eastman et al. (2008) observed that client is the only party reaping the full benefits of BIM. This conclusion aligns with the findings in Table (4), which explicitly demonstrates that the client is the most benefit from the implementation of BIM with the highest score of benefits i.e. 59 out of 59. However, each party acquires the benefits of BIM-based on his/her business function.

2.17 BIM Barriers

(Azhar, et al., 2015) reported that despite the advantages of implementing BIM in construction projects and the growing adoption of BIM in the developed countries such as UK, USA, Europe. Many stakeholders in developing countries are

reporting specific barriers that hinder BIM implementation which resulted in BIM is growing slowly. Barriers of BIM have a different perception from a different point of views i.e. BIM users and non-users (Eadie, et al., 2014; Harty & Laing, 2010).

Several researchers summarized the barriers to implementing BIM as following:

(Panuwatwanich, et al., 2013; Omar, 2015) reported the top barriers to BIM implementation are lack of management commitment to implement BIM" and "the resistance to change, and clinging to the old ways of working. The notable lack of know-how to manage the hindrances for the implementation BIM is the major reason for the modest use of BIM in the AEC industry in MENA area.

(McGraw-Hill, 2012) respectively ordered the top seven barriers that hinder BIM implementation; interoperability, functionality, unidentified BIM deliverables between parties, clients asking for BIM, shortage in staff skilled with BIM, and the need for 3D building product manufacturer. (Lymath, 2014; McGraw-Hill, 2012) concluded that non-BIM users summarized the issues of implementing BIM within AEC Industry firms as there is not enough demand from clients, there hasn't been sufficient time to evaluate BIM, Software, and hardware upgrades are too expensive, Functionality does not apply very well to what we do and there is insufficient BIM-compatible content available for industry needs.

These barriers are caused by a number of technical and human obstacles, which can be classified as either internal or external barriers. The main obstacles are the cost and human-related barriers, primarily the learning of new tools and processes (Kiani, et al., 2015). (Bernstein & Pittman, 2005) emphasised that the major barriers to the full adoption of BIM were transactional to the business process evolution: computability of the digital design information and meaningful data interoperability. In the same vein, (Baba, 2010) grouped the barriers into cost, lack of training, lack of client demand, resistance to change and cultural issues, and interoperable.

Preparing employees and the cost of adopting BIM are some of the problems which shareholders face (Eadie, et al., 2014; Harty & Laing, 2010; McGraw-Hill, 2012).(Eastman, et al., 2011; Hardin & McCool, 2015) claimed that interoperability, cost of hardware and software, and lack of BIM expertise (Eastman, et al., 2011; Hardin & McCool, 2015).One of the most important barriers is the lack of BIM users within the AEC Industry (McGraw-Hill, 2012). (Almutiri, 2016) concluded the main barriers to implement BIM are the lack of experts in BIM, resources, hardware, and software identifying educational gaps for utilizing BIM in architectural programmers. Misunderstanding BIM, the lack of development within architecture education sector in KSA and unacceptable output for AEC industry.(Banawi, 2017) reported that designers or architectural engineering firms

do not usually prove empirically the benefits of BIM to the customer in turn that creates barrier to implement BIM.

(Chan, 2014) claimed the top three barriers to implement BIM are respectively, clients and other project team members did not require BIM, the project parties' belief that 2D CAD systems are enough and the lack of training.

(Mehran, 2016) concluded that the main barriers to implement BIM are Lack of BIM Standards, Lack of BIM Awareness and Resistance to change. (Gerges, M, et al., 2017) Pointed that BIM introduced by software developers one of the considerable barriers to implementing BIM.

Furthermore, the main barriers can be summered as getting seniors to adopt the new methods, changing the organization of staff to suit particular skills (Eastman, et al., 2008; Eastman, et al., 2011), cost of implementation (software and training) , lack of senior management support , scale of culture change required , lack of supply chain buy-in , staff resistance and ICT literacy and legal uncertainties (Eadie, et al., 2014; Eastman, et al., 2008; Eastman, et al., 2011).

Based on conducting an extensive literature review, Table (5), recognised the challenges and obstacles that diminish the chances of implementation of BIM and classified them into five categories as follows:

1. Personal Barriers
2. BIM Process Barriers
3. Business Barriers
4. Technical Barriers
5. Organization Barriers
6. Market Barriers

Table 5: **Recognised Barriers of BIM within the AEC industry**

No.	The barriers	Authors
Personal Barriers		
1	**Lack of insufficient education and training**	(Tse, et al., 2005; Yan & Demian, 2008; McCartney, 2010; Baba, 2010; Forgues, et al., 2011; Bryde, et al., 2013; Banawi, 2017; Matarneh & Hamed, 2017)
2	**Lack of understanding of BIM and its benefits**	(Bryde, et al., 2013; Alhumayn, et al., 2017)
3	**Culture issues/resistance to change/ Lack of skills development**	(Baba, 2010) (Yan & Demian, 2008; Arayici, et al., 2009; Baba, 2010; Forgues, et al., 2011; Construction, M.H, 2012; Awwad, 2013; Ahmed, et al., 2014; Omar, 2015; Almutiri, 2016; Gerges, M, et al., 2017)
4	**Lack of BIM knowledge in applying current technologies**	(Saleh, 2015)

BIM Process Barriers		
1	**The required collaboration, integration, and interoperability**	(Arayici, et al., 2009; Baba, 2010; Forgues, et al., 2011; Sattineni & Macdonald, 2014; Banawi, 2017)
2	**Not all stakeholders are using BIM**	(Liu, et al., 2010; Linderoth, 2010; Elmualim & Gilder, 2014) (Eastman, et al., 2011; Ku & Taiebat, 2011)
3	**Legal and contractual challenges (ownership of data,** traditional procurement methodology**)**	(Ku & Taiebat, 2011; Sebastian, 2011; Elmualim & Gilder, 2014; Migilinskas, et al., 2013; Chien, et al., 2014; Eadie, et al., 2014; Azhar, et al., 2015).
4	**Risks and challenges with the use of a single model (BIM)**	(Saleh, 2015; Banawi, 2017)
5	**Changing work processes (Lack of effective collaboration among project participants)**	(Saleh, 2015)
Business Barriers		
1	**Time and cost** required to train new users	(Sattineni & Macdonald, 2014; Gerges, et al., 2016)
2	**Cost/benefit analysis** (High Cost of implementation (software, hardware upgrade, training, and time), low return-on investment, and expensive upfront costs)	(Yan & Demian, 2008; Lu & Korman, 2010; Baba, 2010; Porwal & Hewage, 2013; Memon, et al., 2014; Gerges, et al., 2016; Gerges, M, et al., 2017; Matarneh & Hamed, 2017)
3	**Unclear benefits**	(Forgues, et al., 2011; Construction, M.H, 2012; Saleh, 2015)
4	**Complicated and time-consuming modelling process**	(Yan & Demian, 2008; Alhumayn, et al., 2017; Gerges, M, et al., 2017)
5	**Have not had sufficient time** to Evaluate	(Construction, M.H, 2012)
6	**Doubts about Return on Investment (ROI)**	(Azhar, 2011; Saleh, 2015)
7	**Lack of contractual arrangements**	(Arayici, et al., 2009; Liu, et al., 2010; Eastman, et al., 2011; Forgues, et al., 2011; Ahmed, et al., 2014; Harrison & Thurnell, 2014; Banawi, 2017)
Technical barriers		
1	**Lack of a BIM specialist**	(Bernstein & Pittman, 2005; Forgues, et al., 2011; Bryde, et al., 2013; Chan, 2014; Memon, et al., 2014; Bui, et al., 2016; Gerges, M, et al., 2017)
2	**Absence of standards and clear guidelines**	(McCartney, 2010; Construction, M.H, 2012; Migilinskas, et al., 2013; Chan, 2014; Harrison & Thurnell, 2014; Volk, et al., 2014; Matarneh & Hamed, 2017)
3	**Difficulty of updating the information in BIM** (time consuming)	(Chan, 2014; Volk, et al., 2014)
4	**Insufficient technology infrastructure**	(Lu & Korman, 2010; Chan, 2014; Bui, et al., 2016)
5	**Functionality not Sufficiently(**added value of BIM is not clear**)**	(Yan & Demian, 2008; Forgues, et al., 2011; Construction, M.H, 2012; Banawi, 2017; Gerges, M, et al., 2017)
6	**Inefficient Interoperability**	(Baba, 2010; Lu & Korman, 2010; Forgues, et al., 2011; Porwal & Hewage, 2013; Chan, 2014; Sattineni & Macdonald, 2014)

7	**BIM file sizes are too large**. Transporting, manipulating, storing or sharing these large files is difficult	(Liu, et al., 2010)
8	**Updating of information**	(Chan, 2014; Volk, et al., 2014)
9	**Current technology is enough**	(Saleh, 2015; Gerges, M, et al., 2017)
Organization Barriers		
1	**The lack of government support**	(Liu, et al., 2010; Chan, 2014; Harrison & Thurnell, 2014; Bui, et al., 2016; Matarneh & Hamed, 2017)
2	Difficulties in managing the impacts of BIM	(Eastman, et al., 2011; Chien, et al., 2014; Azhar, et al., 2015)
3	Absence of other competing initiatives	(Saleh, 2015; Omar, 2015)
4	Resistance to change unwillingness to change	(Sutevski, 2010; Arayici, et al., 2011; Simona, 2012; Jernigan, 2014; Omar, 2015)
5	BIM requires **radical changes** in the workflow, practices, and procedures (magnitude of change, and lack of BIM experience (know-how) to change)	(Yan & Demian, 2008; Arayici, et al., 2009; Garies, 2010; McCartney, 2010; Memon, et al., 2014; Volk, et al., 2014; Gerges, M, et al., 2017)
6	**Required hardware upgrades and software**	(Arayici, et al., 2009; Construction, M.H, 2012)
7	**Financial Issue**	(Thompson & Miner, 2007; Bryde, et al., 2013; Chien, et al., 2014; Azhar, et al., 2015)
8	**Current professional indemnity and insurance terms**	(Chan, 2014; Banawi, 2017)
Market Barriers		
1	**Lack of awareness about BIM**	(Tse, et al., 2005; Arayici, et al., 2011; Forgues, et al., 2011; Bryde, et al., 2013; Ahmed, et al., 2014; Memon, et al., 2014; Gerges, et al., 2016; Matarneh & Hamed, 2017)
2	**The market is not ready yet**	(Porwal & Hewage, 2013; Banawi, 2017)
3	**Lack of client/government demand**	(Tse, et al., 2005; Baba, 2010; Porwal & Hewage, 2013; Chan, 2014; Gerges, et al., 2016; Gerges, M, et al., 2017) (Chan, 2014) (Porwal & Hewage, 2013)
4	**Firms do not convince the client about the benefits of BIM**	(Banawi, 2017)
5	**BIM introduced by software developers**	(Gerges, M, et al., 2017)

The lack of BIM training, the lack of knowledge of the BIM adoption process, lack of support from managers to accept changing current practices, cost of software, the lack of demand and lack of BIM expertise, and lack of practical standards and guidelines, policymakers and the government support were identified as some of the barriers to the adoption of BIM in Saudi Arabia (Alhumayn, et al., 2017; Matarneh & Hamed, 2017).

(Mehran, 2016) categorised the BIM barriers into a technological dimension which includes the interoperability between applications, software compatibility, authorising and monitoring of the quality and progress of construction, design clash detection and visualization and BIM standard and protocols. (Eadie, et al., 2013). An organizational dimension which includes BIM professionals, BIM vendors, professional training of BIM technologies, and support of senior management and clients (Eadie, et al., 2013). An attitude factor which includes

interest in learning BIM, BIM awareness, willingness to use BIM, and perceived cost of BIM technology and platform (Pikas, et al., 2013).

(Nawar, 2014) summarised the barriers as misunderstanding of BIM: People are still comparing BIM to CAD, BIM introduced to Middle East region by BIM's software developers who interlaced BIM to software only**,** Resistance to change**,** Lack of BIM specialists in the region**,** The variety of international BIM protocols and standards**,** Absence of certified BIM educational and consultancy institutes**,** Being conservative towards information sharing**,** Treating BIM as a mandatory requirement**,** None unified standards for BIM practice across the world and The need for industry culture change.

2.18 Removing barriers to BIM adoption

Cost/benefit analysis, raising awareness and BIM education and training are the headline challenges of using BIM (Bryde, et al., 2013). (Eastman, et al., 2011; Hardin & McCool, 2015) reported that the following barriers: (1) Interoperability, (2) cost of hardware and software, (3) lack of BIM expertise, (4) Shortage of client's demand, (5) No sufficient time to evaluate BIM, (6) Software and hardware upgrades are too expensive, (7) functionality is not applicable, and (8) Insufficient BIM-compatible content available for industry needs. Represent the major barriers to implementing BIM in AEC industry. These issues could be addressed by software developers or changing the mechanism of projects' process within construction companies and firms, but this process is likely to take time.

In parallel, (Almutiri, 2016) reported that to solve KSA construction companies' cultural issues and leverage their knowledge about BIM, local companies could seek partnerships with international construction companies that accomplish projects in major construction work using BIM based technologies and processes.

2.18.1 Top management support

Top management has an indispensable role in leading the organisational change to BIM (Herold, et al., 2008), so they should be fully aware of organizational benefits of BIM to improve its performance adding competitive advantages and increasing the profits (Ruikar, et al., 2005; Azhar, et al., 2015). Therefore, top management should be convinced to support this change to take the decision of making BIM as obligatory (Linderoth, 2010).

(Garies, 2010) claimed that due to limited experience and competence to manage BIM implementation, organizational decision makers can learn from advanced BIM-users' previous experiences.

2.18.2 Resistance to change

Resistance to change is one of the mean obstacles impeding BIM implementation (Yan & Demian, 2008; Sebastian, 2011; Elmualim & Gilder, 2014; Eadie, et al.,

2014). (Recardo, 1995) tried to remove this barrier by assuming that data collection serves to identify relative strength of each resistance factors and how it varies by stakeholder group. Also, he reported that if organizations do not provide timely and targeted education, employees will become apprehensive regarding their future job security or job competency.

In parallel, (Kotter & Schlesinger, 1989) suggested that the successful change can be established through two steps: Understanding the need for change and recognizing the benefits than getting ready for the change which involves the people, processes, and technology.

However, other researcher argued that for successful change management and dealing with the resistance to change, two major measures are featured:

1- Bottom-up and top-down approaches should be adopted concurrently (Arayici, et al., 2011).

   (Arayici, et al., 2011) mentioned that effective change starts at the employees' level supported by top management. Communicating and convincing the employees by the top management with their vision of change, serve swift change into BIM, because the change will be bottom-up (Waddell & Sohal, 1998).

   Convincing employees would be through demonstrating the importance of change for them not only for the company, besides illuminating the quite relation between responding to the market changes including changes adoption and acquiring competitive advantages to be sustainable in the market (Ruikar, et al., 2005; Garies, 2010; Arayici, et al., 2011).

2- Applying successful strategies for change management to eliminate any potential change resistance (Arayici, et al., 2009; Eastman, et al., 2011; Arayici, et al., 2011).

   (Waziri, et al., 2014) stated that, the successful organizational change requires systematic and proactive management related to the resistance from people involved in the change. Moreover, (Jung & Joo, 2011) claimed that segregation of change strategy into specific levels of adoption ensures rapid and easy control of the successful implementation of BIM.

(Kotter, 1996) suggested one of the most successful models for BIM implementation segregated into several steps in which: (1) Promoting sense of urgency for the change and transmit it to the employees, (2) Establishing a guiding coalition for the change, (3) Developing an appropriate vision and strategy suitable for the employees and the organization according to its situation,(4) Change should be communicated to all employees to empower others to act on the vision,(5) Creating short win plans, consolidating improvements and sharing the

success with employees, and (6) Anchoring the new approaches to prevent employees from “slipping to the old ways”.

People in Change Management
CHANGE AGENT
Organization
• How does change impact people across the organization?
• How do we make this work for all of us?
Team
• How does each one show up (Acceptance, fear, anger, resistance)
• What can I do to help them cope?
Me
• How do I show up?
• Can I cope?
• What do I need to help me cope?

Figure 23: People in change management (Abas, 2016)

Furthermore, (Abas, 2016) illustrated in Figure 23, how organizations, team and individual might deal with change.

(Kotter & Schlesinger, 1989) suggested that there are six ways of overcoming the resistance to change (Figure 24) Illustrated as following:

Figure 24: Overcoming Resistance to change (Riley, 2015)

Education and communication

Education and honest Communication about proposed measures for the change, help to convince all participants about the logic of changing and clarifying misconceptions including misinformation or inaccuracies. For effective education, it should be delivered consistently and over a long-period for maximum effect.

Participation and involvement

All participants should be involved in a change programme which in turn encourages people especially who would resist. Such programme requires commitment rather than compliance.

Facilitation and support

Kotter & Schlesinger identified “adjustment problems” during change programs. Facilitation and support include further training, counseling, mentoring in addition to listening to participants’ fears and concerns, such measures are in favor of them to efficiently cope with change.

Co-option and manipulation

Co-option includes bringing specific individuals into roles that are part of change management (perhaps managers who are likely to be otherwise resistant to change). Manipulation involves the selective use of information to encourage people to behave in a particular way. Whilst the use of manipulation might be seen as unethical, it might be the only option if other methods of overcoming resistance to change prove ineffective.

Negotiation and bargaining

Negotiation and bargaining might be through offering administrative or financial rewarding for those discouraged to be part of the change process. Negotiation is a common conventional approach in restructuring an organization.

Explicit and implicit coercion

However, coercion might inevitably cause loss of trust between people in a business, this approach can be the last resort for overcoming the problem of resistance to change. Explicit coercion might be through threatening people resisting change virtually, while implicit coercion involves telling those the likely negative consequences for the business as a result of failing change.

2.18.3 Lack of sufficient Education and training

According to (Becerik-Gerber & Rice, 2010) the lack of BIM users within the AEC Industry can be overcome by training the employees. Software providers can provide education and training such as Tekla, one of the international construction companies and software developers, has started to introduce BIM Architectural schools in order to fill a need in the private sector for BIM users. Autodesk works with a local company “Dar Al Riyadh” to leverage the knowledge of students in BIM (Construction Work team, 2014).

The AEC educational sector must be involved to help in graduating AEC professionals well-known about BIM process and technology (Aly, 2014; Vinšová, et al., 2014; Woo, 2006).

2.18.4 Interoperability

IFC is defined as an international public standard schema collectively developed by BIM software vendors. IFC enables the opening or importing BIM files to reuse the created data in other applications using different software; IFC schemes can overcome the conflicts that may appear of using different software of BIM models. (McGraw-Hill, 2009; Smith & Tardif, M, 2009; Liu, et al., 2010; Eastman, et al., 2011; Ku & Taiebat, 2011).

2.18.5 Difficulties of managing BIM Model

Assigning a model manager or as called BIM manager is essential to eliminate the BIM model-related risks who is authorized to edit data for the master federated BIM model (Thompson & Miner, 2007). By controlling the flow of data from or to the BIM model, the BIM manager will be the sole person authorized to enter the data for the master BIM model to develop the BIM final model (Thompson & Miner, 2007). The master BIM model is a collection of several BIM models from different teams to have a final model free of any errors or clashes and ready for the use by the constructor (Hardin, 2009; Eastman, et al., 2011).

2.18.6 Lack of skilled resources and complexity of BIM software

The AEC executives and researchers found that the limited availability of BIM capabilities in AEC market to the lengthy time required for training considering the complexity of BIM software (Liu, et al., 2010; Linderoth, 2010; Ku & Taiebat, 2011; Eadie, et al., 2013; Migilinskas, et al., 2013).

For the sake of providing the market with BIM skilled resources, governments support AEC university students' curriculum with integrated guidelines for BIM training programs in addition to the help of BIM software vendors to enable the the trainees to keep up with the latest BIM skills in the shortest time (Gu & London, 2010; Azhar, et al., 2011; Hore, 2006; Chan, 2014).

2.18.7 Financial Issues:

(Chan, 2014) suggested that "Governments can play a significant role to facilitate the implementation of BIM in the AEC industry, by providing training programs to educate organizations' staff on how to implement and use BIM, governments should offer awareness sessions through professional institutes and academia to promote the organizations' awareness of the significance and benefits of BIM, to encourage them for investing in BIM." (Hore, 2006) suggested that, government's collaboration with software vendors to make training programs.

Singapore Building and Construction Authority (SBCA) fully subsidized training programs to assist organizations to educate their employees on BIM; the goal of SBCA was to mandate BIM by 2015 for all its public projects (Brewer, et al., 2012).

2.18.8 Unclear Intellectual Property Rights (IPR)

Several professional executives and researchers reported that the IPR detailed with responsibilities and rights of all parties and level of data transfer (LOD) should be submitted in a contract document by the government in standard document or by the client. (Gu & London, 2010).

(Bryde, et al., 2013; New Zealand, B.I.M, 2014) proposed practical solutions for IPR problems should guarantee an unrestricted free license to use the model for both parties to maintain the intellectual advantages for designers in parallel to enable the client to get benefit from the BIM model during the project entire lifecycle.

2.18.9 AEC Traditional procurement methodology:

There is a crucial need to change from the traditional to an integrated procurement strategy, which requires a paradigm shift of mindset to accept the changes and reshaping roles and responsibilities, sharing the risks and rewards among the construction players (Hardin, 2009; Sebastian, 2011; Porwal & Hewage, 2013; Love, et al., 2014).

IPD was proposed to be the appropriate construction procurement strategy suitable for BIM, where IPD is defined as a “project delivery approach that integrates people, system, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value of owner, reduce waste, and maximize efficiency through phases of design, fabrication and construction” (AGC, 2010)

Based on BIM core values and IPD definition it is clear that there is mutual synergy between BIM and IPD, where BIM supports the concept of IPD to integrate people and processes, IPD and BIM are built on collaboration principle to optimize the efficiency (AGC, 2010; Glick & Guggemos, 2009; Moreno, et al., 2013; Love, et al., 2014).

Several researchers and professional executives concluded that, the most suitable project delivery method for BIM is the integrated project delivery approach, where all BIM benefits can be reaped such as reducing waste, optimizing productivity, sharing risks and rewards, integrating the fragmented teams and responding to client needs (Hardin, 2009; Azhar, et al., 2011; Eastman, et al., 2011; Moreno, et al., 2013; Jernigan, 2014; Omar, 2015). However, still, the traditional procurement strategies are dominating the AEC industry which creates obstacles to reap the full benefits of BIM (Hardin, 2009).

2.18.10 Doubts about Return on Investment

ROI is not supposed to be measured when BIM is still underdeveloped, its retuning advantages (collaboration, visualization, etc…) should be taken as an overall ROI (Poirier, et al., 2015).

2.18.11 Legal (or contractual) issues

Both Azhar (2011) and (Sai Evuri & Amiri-Arshad, 2015) considered data ownership is one of BIM risks but could be handled with contracts.

2.19 Motivations for BIM implementation in KSA

Some companies in AEC are always seeking for adopting new innovations such as BIM for continuous improvement to stay on the top of the competitive game in the market ((Moore, 2003; Liu, et al., 2010; Eadie, et al., 2013; Omar, 2015).

Majority of construction companies in KSA are international with excellent experience in BIM paving the way for a suitable environment to smoothly transit into BIM (Alhumayn, et al., 2017).

Because the main leverage of implementing BIM is achieving the highest utilization, clients have put a lot of pressure on designers and contractor to rapidly transit to mandate BIM to meet their demands (Almutiri, 2016), (Monko, et al., 2017). The main reasons for adopting BIM in the company are client's requirement, for improvement, competitors are using it, other project parties are using it, Advances in an increased use of information technologies, increased competition due to globalization, and changes in workplace practices and organizational structures (Matarneh & Hamed, 2017).

UK government has already used BIM in governmental project by 2016 which represented a real push for contractors to adopt BIM (Constructing Excellence, 2008) which has reflected on the whole area of Middle East , with the close economic relationship between the UK and the Middle East, which is reflected in the local dominance of British architects and contractors (Gerges, M, et al., 2017).The rapid growth of mega projects in Saudi Arabia, UAE, Bahrain, Qatar and Kuwait, unified language, undifferentiated cultures and using similar standards (mostly American or British) and protocols motivated a wider adoption of BIM in construction processes across the Middle East (Gerges, M, et al., 2017).

The unified language (Arabic), the similarity of Arab cultures, and construction practices within the Middle East use similar standards (mostly American or British) and protocols, motivate the need for a holistic investigation of current BIM practices from different Middle Eastern countries. (Gerges, M, et al., 2017).

(Liu, et al., 2010) categorised the main motivators of BIM implementation are: perceived benefit, external forces, and internal readiness.

2.20 Key factors influence BIM implementation

According to (Chwelos, et al., 2001) study, the adoption of a new technology is affected heavily by three factors: perceived benefit, external forces and internal readiness. Internal readiness mainly includes IT sophistication and top management support.

The implementation of BIM is a relatively long process that requires long duration to reap its real benefits. For example, the UK and Australia planned to mandate BIM in more than four years 2011 to 2016 (Cabinet Office and The Rt Hon Lord Maude of Horsham, 2012; McGrawHillConstruction, 2014)

Several researchers argued that the main factors leverage the BIM implementation are recognising the benefits of BIM and driving forces. Those are the external pressures/forces imposed from externals and/or the surrounding environment (Omar, 2015; Saleh, 2015) such as competitors to adopt the new change to BIM (Liu, et al., 2010; Eadie, et al., 2013).

BIM was stimulated by a number of factors including the need for integrated data management, drive towards whole project lifecycle data management and political pressures calling for effective collaboration between different stakeholders to enhance the quality of the construction industry and cost reduction (McGrawHillConstruction, 2014; Sabol, 2008; Shahrin, et al., 2010; Yan & Demian, 2008).

(Elmualim & Gilder, 2014) (Love, et al., 2014) Argued that traditionally adoption of BIM starts with the recognition of the benefits of BIM and how these benefits can promote the organization's competitive advantage, increase ROI and eradicate the majority of the traditional AEC problems.

(Alhumayn, et al., 2017) suggested strategies for implementing BIM in KSA include providing legislation and a supportive regulatory environment, the government assists funding, more educated key players and gaining the experience from advanced countries use BIM. The successful implementation of BIM in Saudi Arabia requires a top-down strategy that facilitates the smooth flow of information. As the main challenges of adopting and implementing BIM include government and top management support. The successful implementation of BIM for construction in KSA motivated transformation from previous methodologies characterised by the physical movement of paper-based designs and written communication from government officials to more electronic communication via a standard platform.

(Construction, M.H, 2012) concluded the most important factors for Increasing BIM benefits are: improved interoperability between software applications, improved BIM software functionality, more clearly-defined BIM deliverables between parties, more owners asking for BIM, more 3D building product manufacturer content, reduced cost of BIM software, more internal staff with BIM skills, more use of contracts to support BIM, more external firms with BIM skills and more entry-level staff with BIM skills.

(Mehran, 2015) Argued that the main factors influencing BIM implementation; government support, BIM contract, standards and protocols, develop BIM

performance matrix and industry collaboration. (Won, et al., 2013) Identified five factors for collaboration and integration within BIM as (Product information sharing, Organizational roles synergy, Work process coordination-Environment for teamwork, Reference data consolidation).

Suitable directions can be suggested for the government, professional bodies and BIM vendors to foster the local use of BIM (Mehran, 2015).

However (Arayici, et al., 2011) suggested that Approaches Adoption should be undertaken with a bottom-up approach rather than top-down approach, (Omar, 2015; Alhumayn, et al., 2017) Claimed that to rapid the BIM implementation the government has to mandate BIM which represents top-down approach.

After an extensive literature review, Table (6), illustrate the main factors influencing the BIM implementation.

Table 6: Literature review Key factors influence the Adoption of BIM

No.	Key factors influence the Adoption	Authors
External Push for Implementing BIM		
1	**Government pressure** (Intervention in mandating BIM)	(Eadie, et al., 2013; Porwal & Hewage, 2013; Omar, 2015; Saleh, 2015; Willis & Regmi, 2016)
2	**Client pressure** and demand the application of BIM in their projects	(Saleh, 2015; Almutiri, 2016)
3	**Government support**	
Coordinated government support and leadership		(Arayici, et al., 2011; Chan, 2014; Smith, 2014; McPartland, 2017)
Developing industry-accepted BIM standards, best practices, and legal protocols		(Construction, M.H, 2012; Chan, 2014; Smith, 2014; Willis & Regmi, 2016; McPartland, 2017)
The government collaborate with the industry, professional bodies and education institutes to establish standards, guidance, to provide training to practitioners and future students and Defining levels of BIM working for reference in professional services agreement		(Chan, 2014; Smith, 2014; McPartland, 2017)
Set realistic goals , not to make things too complicated, Plan for the worst, Find a partner and Provide high-end hardware resources and networking facilities to run BIM applications and tools efficiently		(McPartland, 2016)
A structured set of BIM competencies		(Succar, et al., 2013)
Having established industry-wide rules and protocols governing accessing and updating.		(Willis & Regmi, 2016)
Developing suitable contractual arrangements		(Arayici, et al., 2011; Migilinskas, et al., 2013)
4-other external pushes		
Raising awareness (promotion and awareness of BIM)		(Succar, 2009; Azhar, 2011; BIM Academic Fourm, 2013; Kocaturk & Kiviniemi, 2013; Almutiri, 2016; Gerges, M, et al., 2017)
Provide education at university level		(Tzonis, 2014; Omar, 2015; Saleh, 2015; Almutiri, 2016)
Developing BIM data exchange standards, rules and regulations		(Chan, 2014; Saleh, 2015; Mehran, 2016)

Providing guidance on use of BIM	(Gu & London, 2010; Saleh, 2015; Mehran, 2016)
contractual arrangements	(Deloitte, 2016; Mehran, 2016)
BIM required by other project parties	(Construction Work team, 2014; Saleh, 2015)
Competitive pressure	(Azhar, 2011; Gu & London, 2010) (Liu, et al., 2010; Eadie, et al., 2013)
Clients provide pilot project for BIM	(Saleh, 2015)
Collaboration with universities (Research collaboration and curriculum design for students)	(Saleh, 2015; Almutiri, 2016)
Perceived benefits from BIM to client	(Gu & London, 2010; Azhar, 2011)
Availability of appropriate software and hardware tools	(Gu & London, 2010; Azhar, 2011)
Internal Push for Implementing BIM	
Top Management support	(Rainer & Hall, 2002; O'Connor & Basri, 2012; Herranz, et al., 2013; Gerges, et al., 2016; McPartland, 2017)
Cultural change (resistance to change)	(Chwelos, et al., 2001; Hardin, 2009; Liu, et al., 2010; Gerges, et al., 2016)
Collaboration between all project participants	(Arayici, et al., 2011; Migilinskas, et al., 2013; Gerges, et al., 2016; Willis & Regmi, 2016)
Improving built output quality	(McCartney, 2010; Saleh, 2015)
Perceived benefits from BIM (concerted efforts to make clients demanding BIM)	(Sebastian, 2011; Azhar, 2011; Eastman, et al., 2011; Elmualim & Gilder, 2014; Omar, 2015; Saleh, 2015)
Technical competence of staff	(Arayici, et al., 2009; Saleh, 2015; McPartland, 2017)
Financial resources of organization	(Liu, et al., 2010; Eastman, et al., 2011; Succar & Kassem, 2015; Omar, 2015; Saleh, 2015)
The desire for innovation with competitive advantages and differentiation in the market.	(Omar, 2015; Saleh, 2015)
Improving the capacity to provide whole-life value to client	(Omar, 2015; Saleh, 2015; Gerges, et al., 2016)
Safety into the construction process (reduce risk of accident)	(Omar, 2015; Saleh, 2015)
BIM training program to staff	(Arayici, et al., 2011; Eastman, et al., 2011; Smith, 2014; Gerges, et al., 2016; Willis & Regmi, 2016; Gerges, M, et al., 2017)
Adapting existing workflows to lean oriented processes	(Arayici, et al., 2009; Arayici, et al., 2011; Eastman, et al., 2011)
Decide which tools you will use	(McPartland, 2016)
apply successful change management strategies to diminish any potential resistance to change	(Arayici, et al., 2009; Arayici, et al., 2011; Eastman, et al., 2011)
Collaboration between all stakeholders	(Arayici, et al., 2009; Eastman, et al., 2011; Gerges, et al., 2016; Willis & Regmi, 2016)
Continuous investment in BIM	(Ding, et al., 2015; Saleh, 2015)
Projects complexity and profit declination	(McGraw-Hill, 2009; Elmualim & Gilder, 2014; Jernigan, 2014; Azhar, et al., 2015; Omar, 2015; Almutiri, 2016; Ball, 2017)
Approaches Adoption should be undertaken with a bottom-up approach to successful change management and deal with the resistance to change.	(Arayici, et al., 2011)

(Liu, et al., 2010; Eadie, et al., 2013) concluded that the driving forces for the implementation of BIM classified to the government and client pressure,

surrounding environment, pressure from competitors and the complexity of projects and profit declination.

2.21 AEC industry and organizational internal readiness

Organisational internal readiness is mainly affected by four factors: (1) Organisational decision, (2) Attitude of top management towards BIM implementation, (3) Flexibility level of organisations to change, (4) Financial readiness for funding. (Mitropoulos & Tatum, 2000; Ruikar, et al., 2005; Liu, et al., 2010; Eadie, et al., 2013; Omar, 2015; Saleh, 2015). (Gu & London, 2010) suggested evaluation and proper assessment of these factors to assure the internal readiness of organisations.

Furthermore, (Gu & London, 2010) claimed that people, process, and product are the essential controllers for organisational readiness.

2.22 Suggested strategies and Methodologies for BIM implementation

(Arayici, et al., 2011) claimed that setting a clear guidance and methodology guarantees to achieve the ultimate benefits of BIM.

Several researchers developed frameworks, models, and methodologies to implement BIM as follows:

(Olugboyega, 2017) Suggested framework to create a BIM environment (he claimed that it can be created when BIM has been adopted or implemented) as follows: (1) Acquiring BIM software technologies (according to the project goals) and BIM hardware, (2) Developing BIM contents library, (3) Developing a BIM standard, and (4) Setting up a BIM platform (interoperability tools, Collaboration tools, integration tools, coordination/ clash detection tool and Communication tools) according to the types of BIM software and BIM hardware.

In figure 30, (Wang, et al., 2013) developed a BIM user acceptance model applying technology acceptance model (TAM) and relevant theories.

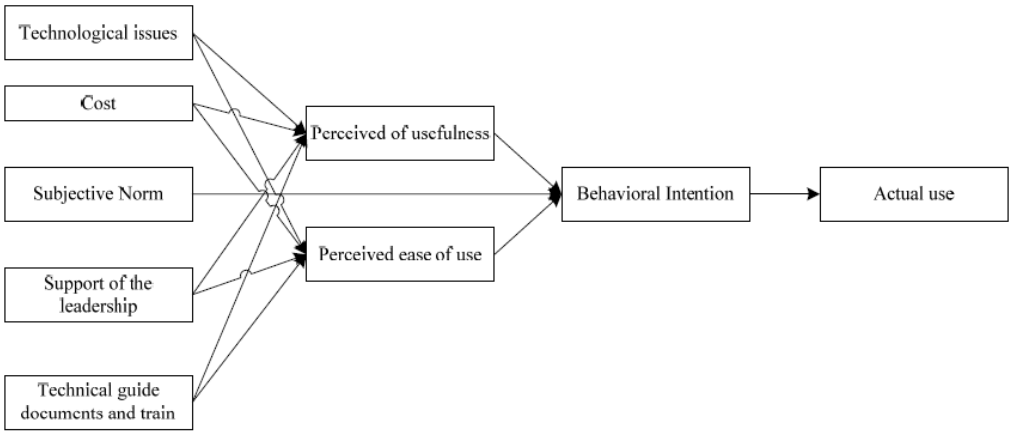

Figure 25: BIM Users Acceptance Model (Wang, et al., 2013)

(Courtesy of Adam Matthews, Chair, EU BIM Task group) suggested another strategic framework for public sector BIM adoption: growing capability, pilot projects, measuring and monitoring, case studies and embedding change.

(Jung & Joo, 2011) proposed BIM implementation framework (Table 7).

Table 7: The BIM implementation framework (Jung & Joo, 2011)

Technical (T)	Perspective (P)	Construction Business Function (C)		
1.Data Property 2. Relation 3. Standards 4. Utilization	1. Industry 2. Organization 3. Project	1. R&D 2. General Admin. 3. Finance 4. HR. mgt. 5. Safety Mgt.	6. Quality Mgt. 7. Cost control 8. Contracting 9. Materials Mgt. 10. Scheduling	11. Estimating 12. Design 13. Sales 14. Planning

2.23 The future of BIM in the KSA

According to (Jernigan, 2014), the worldwide change into BIM is inevitable, therefore, countries who are not keeping up with that new innovative transit will be soon out of competition game

Following the promising steps (due to the government's efforts) of Malaysian construction industry in promoting BIM (Latiffi, et al., 2013), could be beneficial for KSA such as using data of a self-assembly 3D printer; which will be in level 5 after 2030 (BIM2050group, 2014).

The partnership between Tekla's parent company Trimble, and Gehry Technologies (the technology company created by the world-renowned architect Frank Gehry) is considered a real step on the road of enhancing BIM adoption in the kingdom (Saudi Gazette, 2014).

A further increase adoption of BIM in construction across KSA can be expected, due to various international companies firms have multiple offices across KSA which executing mega and complex (Gerges, et al., 2016).

(Construction Work team, 2014) predicted a 17.8% growth in the market value of BIM rising from $2.6bn up to $6.5bn by 2020 stimulated by the general recovery of construction markets worldwide and raised recognition of BIM benefits. Also predicted further growth will be motivated by companies using the data for building maintenance and operations, and that integration with building energy management systems represents the next major step in its growth.

2.24 Knowledge Gaps

There is a need for further studies on BIM awareness, BIM definitions, changes, and how these challenges should be addressed. A common and agreed upon definition of BIM needs to be developed, as well as a methodology to evaluate BIM benefits from a business perspective. An accepted and validated baselines and/or benchmarks are needed (Mehran, 2016).

There is a little research on BIM in KSA. Almost no research on BIM in developing countries exists prior to 2013, and the focus of the present researches is limited to the three countries of China, India, and Malaysia. (Bui, et al., 2016).

The study is trying to cover six knowledge gaps: raising BIM awareness, Barriers diminishes implementation of BIM in KSA, ways to overcome these barriers, BIM Benefits, key factors influencing the implementation of BIM, and Methodology to implement BIM in KSA.

However (Farah, 2014) discussed the BIM awareness in KSA, benefits can gain from implementing BIM, barriers and key factor influencing the adoption, his study rely only quantitative data also his findings missed many points which already stipulated in many literature reviews such as his result about the benefits of BIM are only Collaboration and Coordination, Productivity, Changes in workflows and processes And Market Opportunities however in section 2.16 illustrate many key additional benefits.

Despite (Banawi, 2017) investigate the barriers to BIM implementation in KSA , the study limited to the public projects, he rely on a case study which explore one project in Rabigh , from the extensive exploring the literature review it obvious that most of the barrier is considered as a barrier or not the main barriers and can be secondary ones, for example, the barrier of the market is not ready (Gerges, M, et al., 2017) confirmed that in Saudi Arabia market due to the rapid growth of mega and complex projects the market imposes the organizations to adopt and implement BIM. And section 2.17 in this study illustrate many other key barriers that Badawi's research doesn't deal with.

In spite of (Alhumayn, et al., 2017) concluded the barriers and strategies of implementing BIM in KSA his study rely on only quantitative data as distributing questionnaire which this method has its disadvantages and limitations also after an extensive literature review his research missed many key barriers and strategies.

Based on the extensive literature survey, it was found that there is no specific research investigated the KSA AEC industry to propose solution packages for the government to implement BIM. In order to fill this knowledge gap, this research prudently investigated all these gaps and proposed efficient solutions that assist KSA government to implement BIM smoothly and swiftly.

Chapter 3: Research Methodology and Data Collection

3.1 Method of data collection

The literature review developed a profound understanding for the six independent variables: raising awareness about BIM, the perceived benefits, barriers hinder the implementation, removing the barriers, key factors influencing the adaption and the internal readiness and of AEC industry and organizations capability for implementing BIM.

Due to the quantitative research methods limitations and weakness; improper representation of the target population, lack of resources for data collection, inability to control the environment, limited outcomes, expensive and time consuming, difficultly in data analysis and requirement of extra resources to analyses the results (Sudeshna & Datt , 2016),and limitations of qualitative research; findings cannot be extended to wider populations with the same degree of certainty that quantitative analysis can, Ambiguities, which are inherent in human language, can be recognized in the analysis and The aim of qualitative analysis is a complete, detailed description. No attempt is made to assign frequencies to the linguistic features which are identified in the data, and rare phenomena receive (or should receive) the same amount of attention as more frequent phenomena (Atieno, 2009). The mixed methods selected to conduct this research to reap the benefits of all methods and overcome the limitations and weakness of each method.

The research methodology consists of three phases (Figure 26):

First phase: an extensive literature review to build a deep understanding to cover the stipulated research scope.

Second phase: the aim of the second phase is to explore each point and contents or steps to develop a suggested methodology. The second phase consisted of two steps the first is a questionnaire and the second is interviews to collect the BIM user and non-user perceptions about each step that produces the suggested methodology to implement BIM in KSA.

First step: Prepare a structured questionnaire survey which extracted from an understanding of the literature review to be distributed via mail, professional's websites groups like LinkedIn, social media professionals' groups like Facebook and tweeter. Also, the questionnaire link distributed to the organizations that are registered as members of Saudi Chambers which includes the entire KSA AEC industry players. In addition to organizations that are registered in Ministry of Municipal and Rural Affairs and municipalities for each region, avoiding duplications was considered. Additionally, Saudi Council of Engineers published the questionnaire in its monthly magazine.

In addition to that structured interviews to fill the questionnaire via telephone and face to face interviews. The questionnaire includes quantitative and qualitative data so the two approaches were taken into consideration.

A pilot sample: Prior to finalizing the questionnaire, in October 2017 a pilot sample of a carefully selected 12 professionals with average experience of 8 years in the KSA AEC industry. Where six of them represent BIM users and the others six represent BIM non-users. These veteran professionals were selected from local and multinational AEC organizations in the KSA market. The initial questionnaire was refined based on the feedback received from the pilot sample of the 12 professionals.

Afterwards, the final questionnaire was developed to collect the data, and hence the final questionnaire was accessible via online survey platform dubbed “Google form”. This platform enabled easy and swift filling of the survey via the internet and then the responses were gathered automatically to save and store them via an online database.

There are three different types of the data collection techniques under the self-completed method: internet /intranet, post and delivery, and collection. The use of the internet to distribute and collect data will help to cover a large sample in a short period of time compared with other techniques. Using the internet technique has a high confident that the right person will respond to the questionnaire. However, if the respondent has not got it through a direct link by his/her personal email the rate will be negatively affected.

On the other hand, the response rate in using the internet techniques is the lowest rate compared with other techniques by 11% (Saunders, et al., 2012). Avoiding time-consuming this study, use a multi-method quantitative data which are an online questionnaire and structured interviews. The link to an online questionnaire was sent by email to increase the confidentiality. The questionnaire was available from 28th September 2017 till 20th December 2017 (about three months).

The questionnaire survey consists of eleven sections. Section 1 consists of general information, respondents’ personal information and demographics such as profession, years of experience in KSA, academic qualifications. Section 2 consists of respondents’ awareness of BIM, BIM user or non-user, BIM Software that his/her Company use, BIM applications, beneficial integrating with BIM, BIM Maturity Levels, the future of BIM …. etc. In section 5, 6, 7, 8, 9 and 10 each respondent was asked to rate to what extent he/she agree/disagree with each of the perceived benefits of BIM, barriers for the implementation of BIM, main factors Influencing the adoption of BIM in KSA and the AEC organizations capability to implement BIM, on a five-point Likert scale ranging from 1 to 5, where 5 represents ‘Strongly agree’, and 1 represents “Strongly disagree”.

The questionnaire was developed to collect the data from two groups (BIM users and BIM non-users) who work in the KSA AEC industry. Both groups responded to the same questionnaire.

The questionnaire survey was sent to 689 AEC medium to big organizations in the KSA, however, the returned responses were 275 responses (13.0 %), the uncompleted responses were 27 (9.7%) of the returned responses. Therefore, the number of true responses were 248 (90.18%) of the returned responses.

Second step: Prepared structured interviews with AEC industry professionals whether using BIM or not from deferent organizations and different sizes small medium and large organizations.

Third phase: the third phase consisted of two steps the first is an online questionnaire and the second is interviews to validate the suggested methodology to implement BIM in KSA AEC industry projects from only BIM user's perspectives.

As the first step for the third phase, we collected the maximum number of responses to the selected quantitative approach to understanding the impact of the six independent variables on the implementation of BIM in the KSA AEC industry (the dependent variable). Therefore, the quantitative approach was found as a reliable methodology to test the hypotheses composed of variables derived from the first and the second phases (Naoum, 2012).

As the second step for the third phase, structured interviews with focus groups, who are BIM expert and BIM researchers, were used to validate the developed model.

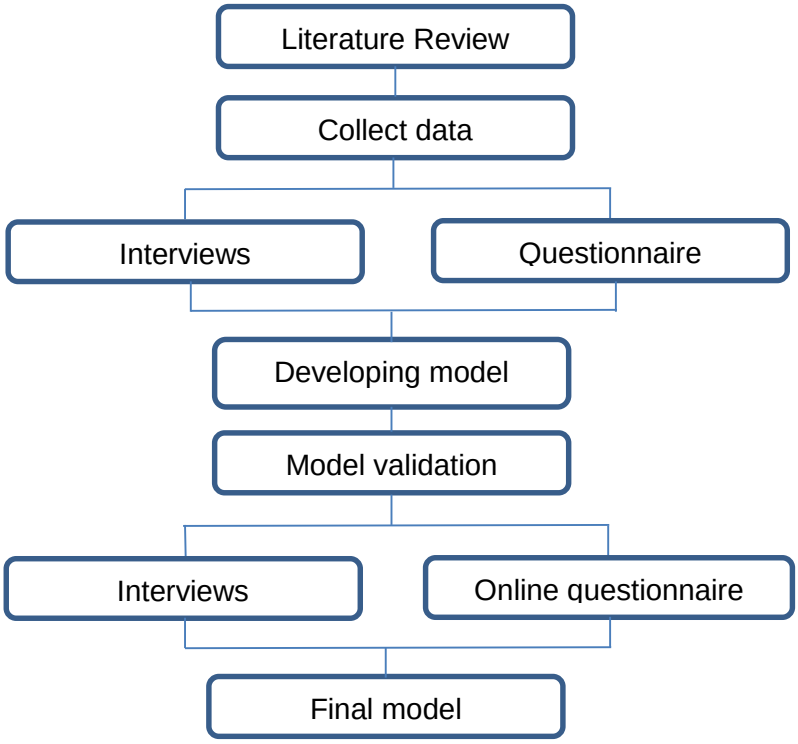

Figure 26: Research Methodology flow chart

3.1.1 The Population and Sample Size

It was possible to collect data from the entire population. However, that would have been time-consuming and it would have affected the budget (Saunders, et al., 2012).Therefore, using the sample size helped to get the required result with the right budget within the time given.

The sample is a small proportion that acts as a representation of the total targeted population. The target research sample for this research study included all professionals whether they have a good knowledge and experience about BIM technology or not and whether they have a working specialization related to the AEC industry (Civil Engineers, Architects, Electrical Engineers, Mechanical Engineers, etc.) in the KSA market or not. It is almost impossible to calculate the exact number of the total targeted population as the number of engineers in Saudi Arabia according to Saudi Council Engineer (Aleqt, 2017) is 230943. Also for more accuracy and as an extra reference, the website (www.linkedin.com) was checked for the total number of engineers who has the location KSA. At the time of the research, they were 211340. For more accurate estimates, we have taken the largest number, which resulted 231000 as the target research population. Statistical equations were used to calculate the sample size required. Three different statistical equations were used and the equation resulting in the largest sample size was used.

Equation 1 – Cochran Formula

$$n = \frac{z^2 * p * q}{c^2}$$

Z = Z value, taken as 1.96 for 95% confidence level.
P = Percentage picking a choice, expressed as a decimal, taken as 0.5.
q = 1 – P.
C = margin of error, taken as 9% = 0.09.
N= Total population, taken as 231,000.
n= Sample size.

Applying the equation: $n = \frac{1.96^{\,2} * 0.50 * (1-0.50)}{0.09^2}$ =118.57 ≈ 119

Equation 2 – Slovin's Formula

$$n = \frac{N}{1 + N\,(c^2)}$$

C = margin of error, taken as 9% = 0.09.
N= Total population, taken as 231,000.
n = Sample size.
Applying the equation: $n = \frac{231000}{1+231000\,(0.09^{\,2})}$ =123.39 ≈124

Equation 3

$$n = \frac{(z^2 * p * q) + c^2}{c^2 + \frac{z^2 * p * q}{N}}$$

Z = Z value, taken as 1.96 for 95% confidence level.
P = Percentage picking a choice, expressed as a decimal, taken as 0.5.
q = 1 – P.
C = margin of error, taken as 9% = 0.09.
N= Total population, taken as 231,000.
n = Sample size.
Applying the equation: $n = \frac{(1.96^2 * 0.50 * (1-0.50)) + 0.09^2}{0.09^2 + \frac{1.96^2 * 0.50 * (1-0.50)}{231000}}$ = 119.50 ≈ 120

Thus the result of Equation 2 = 124 was chosen to be the required sample size of this research study.

3.2 Reliability and testing the questionnaire data

3.2.1 Reliability

Reliability is the overall consistency of a measure. The acceptance value for alpha if it equals to 0.70 or higher (Mirghani, 2016).

Table 8: Reliability Statistics

Cronbach's Alpha	N of Items
.984	85

Cronbach's Alpha equals to 0.984 that means the data collected from the questionnaire with highly reliable as shown in Table (8).

3.2.2 Correlation

This is a technique that can show whether and, how strongly pairs of variables are related. P-values are often coupled to a significance or alpha (α) level, which is also set ahead of time, usually at 0.05 (5%). Thus, if a p-value was found to be less than 0.05, then the result would be considered statistically significant and the null hypothesis would be rejected. However, other significance levels, such as 0.1 or 0.01, are also used; depending on the field of study (Mirghani, 2016).

Table 9: Correlations

		Ensuring Project Requirements	Enabling several marketing techniques	Evaluating project performance & maintenance	Reducing financial risk	Information Model
Ensuring Project Requirements	Pearson Correlation	1	.666**	.628**	.629**	.703**
	Sig. (2-tailed)		.000	.000	.000	.000
	N	98	98	98	98	98
Enabling several marketing techniques	Pearson Correlation	.666**	1	.564**	.544**	.536**
	Sig. (2-tailed)	.000		.000	.000	.000
	N	98	98	98	98	98
Evaluating project performance & maintenance	Pearson Correlation	.628**	.564**	1	.580**	.587**
	Sig. (2-tailed)	.000	.000		.000	.000
	N	98	98	98	98	98
Reducing financial risk	Pearson Correlation	.629**	.544**	.580**	1	.752**
	Sig. (2-tailed)	.000	.000	.000		.000
	N	98	98	98	98	98
Information Model	Pearson Correlation	.703**	.536**	.587**	.752**	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	98	98	98	98	98

**. Correlation is significant at the 0.01 level (2-tailed).

The value was found to be less than 0.05, then the result would be considered statistically significant (Table 9).

3.3 Respondents General information

The received responses are 272 while 63.1 % selected No and, finish the questionnaire because they do not have enough knowledge to continue. However, 36.9 % selected “Yes, and continued answering the questions” as shown in Figure (27). This percentage means that there is lack of awareness about BIM Knowledge in KSA. In spite of what literature stated according to (Farah, 2014) reported that there is a high level of awareness of BIM technology in KSA AEC industry.

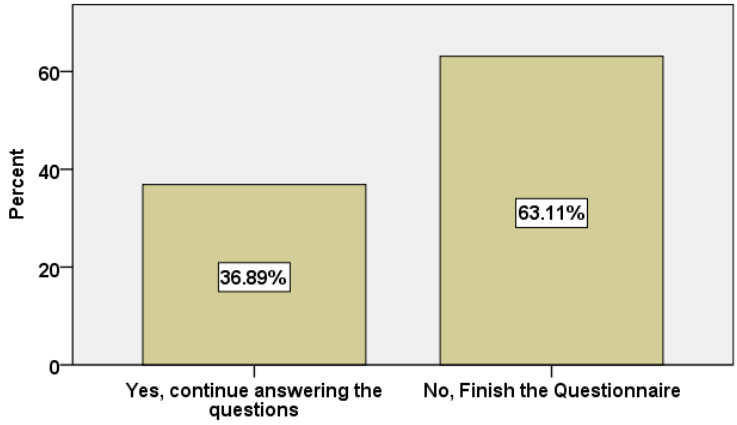

Figure 27: Respondents knowledge about BIM

As shown in Table (10), the reasons that some respondents provided for not being interested in BIM.

Table 10: Coding respondents’ reasons why they do not have interest in BIM

Reasons	Frequencies	Percent
CAD is enough	3	9.09%
Don’t know what BIM is	10	30.30%
Depends on customer	3	9.09%
have no time	4	12.12%
it is out of my scope	10	30.30%
Not needed in my work	3	9.09%
Total	33	100 %

The largest percent reported, ”Don’t Know what BIM is and it is out of my scope.” Hence, this percentage implies raising the BIM awareness influence the BIM adoption.

Figure (28), dissected the completed responses represent 25.4 % public sector organizations and 74.6 % private sector organizations. This result means that the public sector is less interesting in BIM than the private sector.

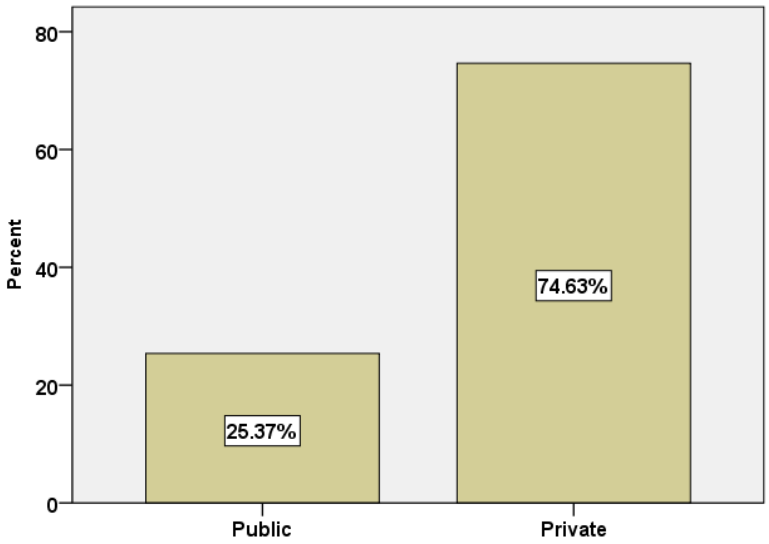

Figure 28: Responses' Organization type

Table (11), concludes that residential buildings represent 38.6% of the largest percentage of respondents' specializations.

Table 11: Organization specialization

Organization specialization	Responses	
	N	Percent
Residential	105	38.60294
Commercial	94	34.55882
Industrial	72	26.47059
Health-care	53	19.48529
Environmental	48	17.64706
infrastructure	104	38.23529
Academic	62	22.79412
Other Specializes	9	3.308824
Total	272	100

As shown in Table (12), the highest organization size 64.0% are over 200 employees; it means that large companies are interested in BIM while the small and medium have less interest.

Table 12: Organization size

Organization size	Frequency	Percent
1-30	33	12.1
31-60	33	12.1
61-100	12	4.4
101-200	20	7.4
Over 200 Employees	174	64.0
Total	272	100.0

A large percentage of respondents' organizations (35.52%) are working on big size projects (501M -1Billion), as shown in Figure (29).

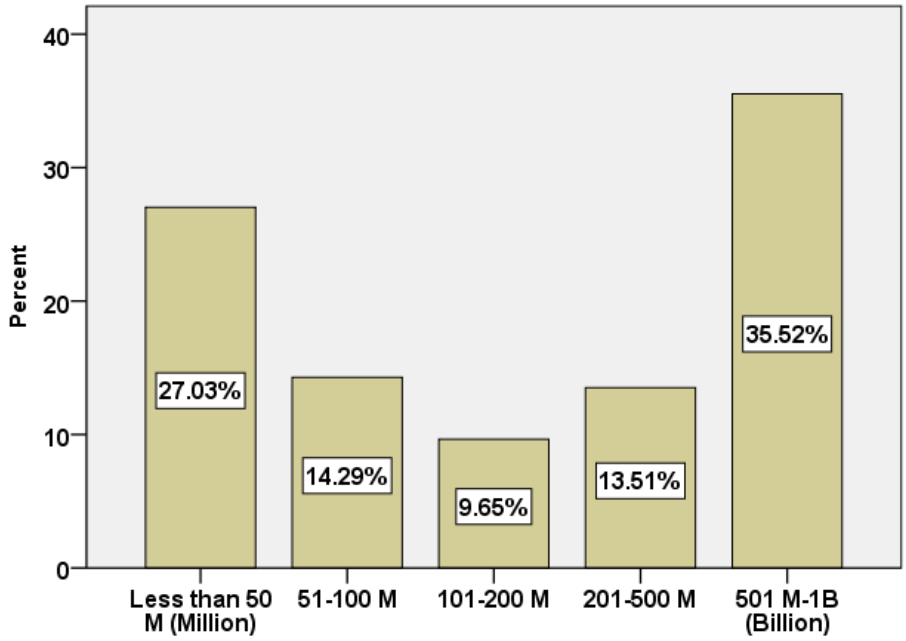

Figure 29: project budget

The largest percentage of the respondents (36.76%) are project/section manager (Figure 30). This means that managers are more interested in using BIM.

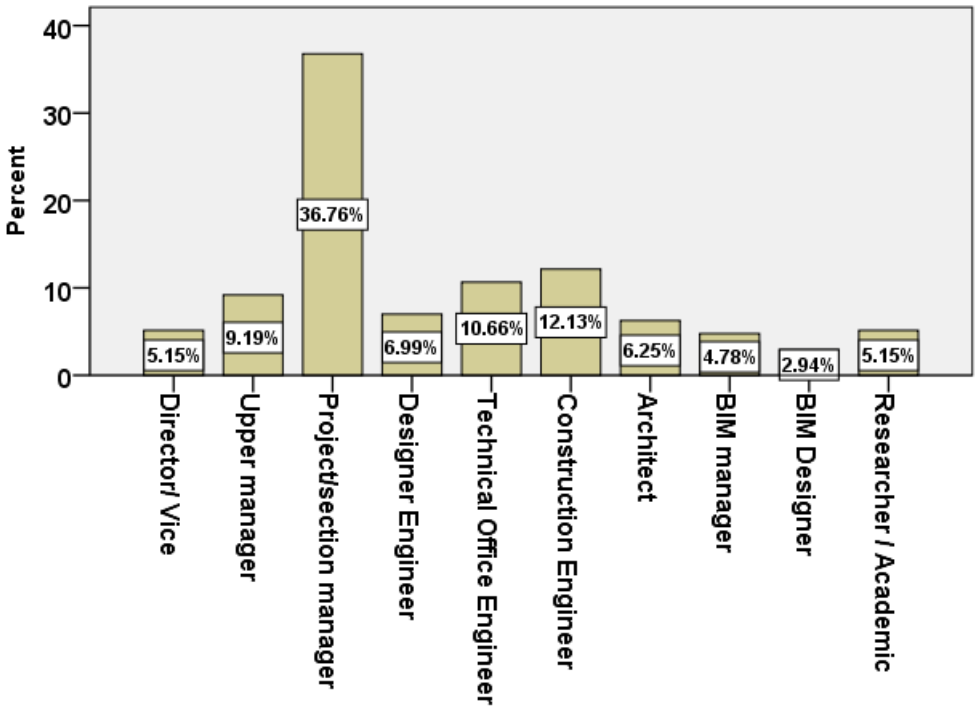

Figure 30: Respondents Position

As shown in Figure (31), most respondents (29.36%) reported that they represent a Designer / Architect / Engineer. This means that designers are more aware of BIM.

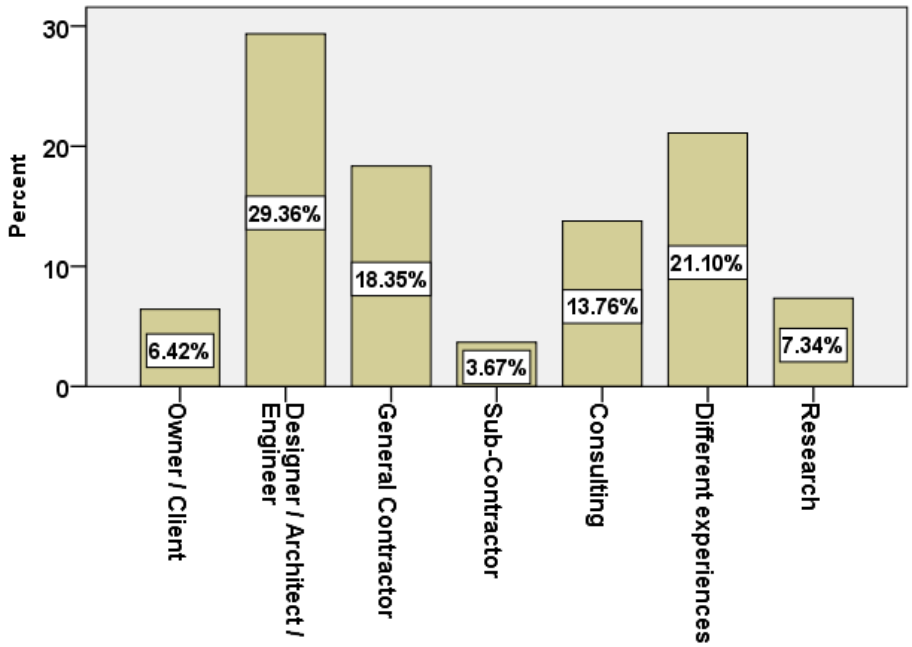

Figure 31: Respondents Role

Most of the respondents' educational level is B.Sc. (69.85%), as shown in Figure (32). This indicates that the first tangibles with the BIM are whose educational degree is BSc.

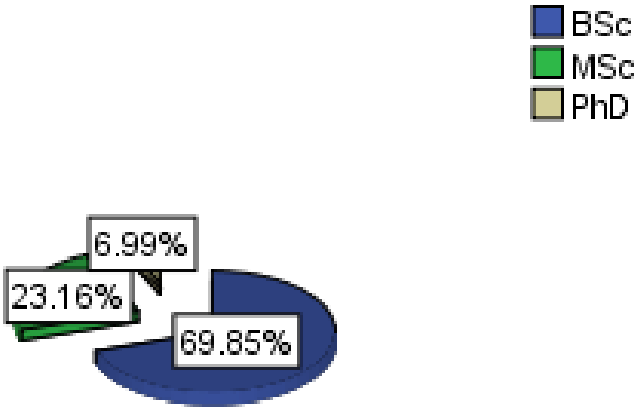

Figure 32: Respondents Education Level

The most of respondent's years of experience are 5-10 years (37%) as shown in Figure (33). This is referred that there is lack of BIM education and training for fresh graduates and the university students, which stated as a barrier to BIM implementation.

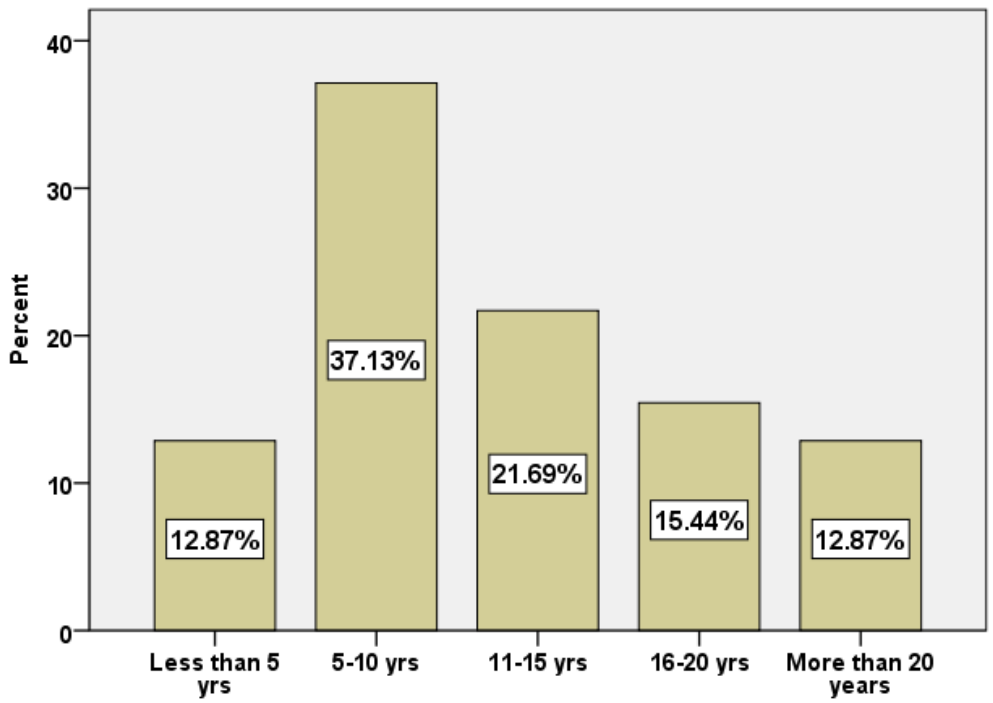

Figure 33: Respondents years of experience

The randomly tested sample covered all the KSA as shown in Figure (34), however the received responses mostly from Riyadh 41.2%, Makka al-Mukarama 13.2%, Eastern Province 6.3 %, Madinah 4.8%, Najran 2.9%, Tabuk 1.8%, Qassim 1.8%, Asir and Jazan 1.8 %, Northern Borders 0.7%, Jawf 0.70%, Ha'il 0.4%, Bahah 0.4%.

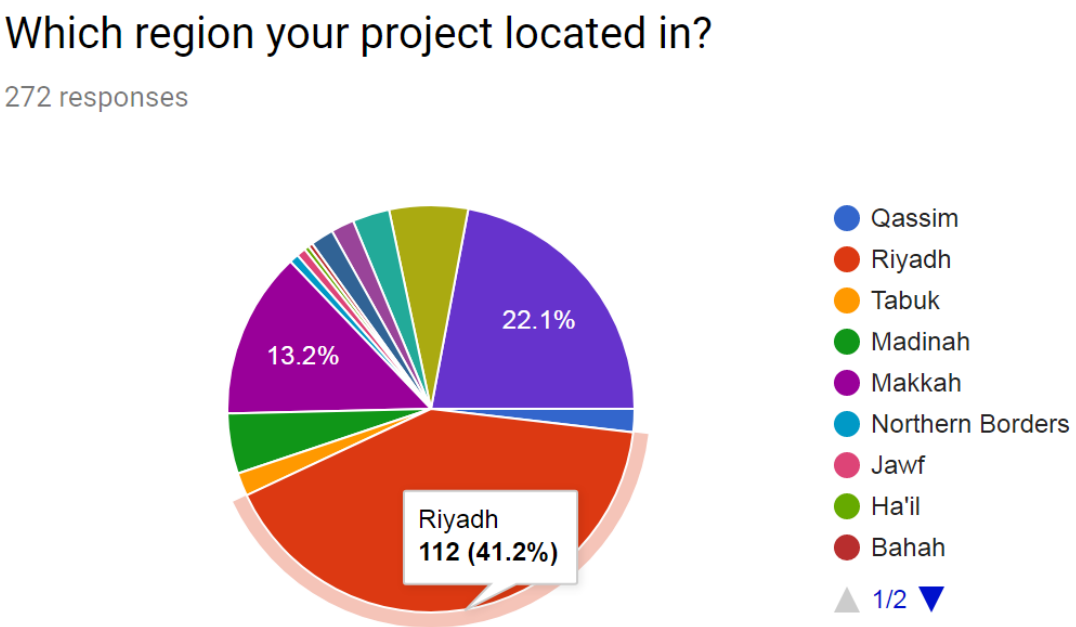

Figure 34: Responses' projects located in KSA

Chapter 4: Results analysis

This study tried to compare between BIM users and non-BIM user's perspectives of BIM awareness level in KSA, perceived BIM benefits, barriers to BIM implementation, the solution to overcome the barriers, the key factors influencing the BIM implementation, the AEC industry, and internal readiness, find suggested methodology to implement BIM in KSA.

4.1 Questionnaire

Figure (35), reflects the limited awareness about BIM representing 60% of the whole returned responses, whereas 15.6% are not interested, 44.4% not using BIM. While 17.8 % BIM user, 12.2 % as BIM experts and 9.3% as BIM researcher, this means that only 40% are aware of BIM in KSA. Therefore, the critical success factors are related to raising the awareness of the AEC industry key players and decision makers about BIM. This result contradicts with what (Farah, 2014) found.

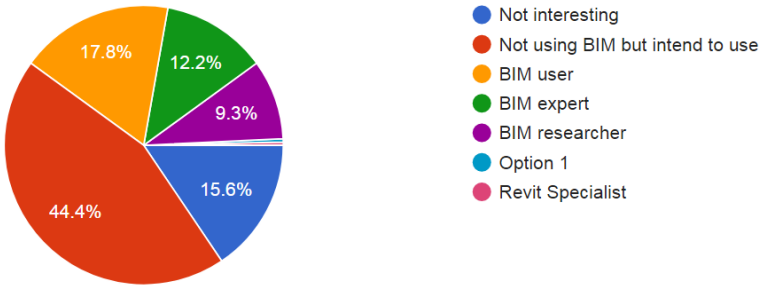

Figure 35: Awareness about BIM

A large percentage of respondents (71.90%) uses the Revit software as shown in Table (13). This result is similar to that reported in the literature (Gerges, M, et al., 2017).

Table 13: BIM software

BIM software	Responses	
	N	Percent
Revit	87	71.9%
Archi CAD	5	4.1%
Vico	1	0.8%
Bentley	5	4.1%
Vector Works	1	0.8%
Naviswork	17	14.0%
Tekla Structures	5	4.1%
Total	121	100.0%

4.1.1 Respondents information about BIM

The respondents' answers about the different areas of BIM application are reported in Table (14). This result confirms with that reported in the literature.

Table 14: BIM Applications

BIM Applications	Responses	
	N	Percent
Interaction with non-professionals	38	6.8%
Design analysis	62	11.2%
Drawing production	71	12.8%
Project scheduling programming	52	9.4%
Cost Estimating	60	10.8%
Tendering	53	9.5%
Quantity Surveying	66	11.9%
Site layout planning	42	7.6%
Support constructability and analysis	42	7.6%
Collaboratively	47	8.5%
Safety	23	4.1%
Total	556	100.0%

Table (15), presents the different areas that can be integrated with BIM as per the respondents' answers. The project management comes as the first area that is usually integrated with BIM. These results are in line with the literature.

Table 15: Integration with BIM

Integration with BIM	Responses	
	N	Percent
Lean Construction	50	8.7%
Geography information system (GIS)	41	7.1%
Enterprise Resource Planning (ERP)	39	6.8%
Virtual Reality	57	9.9%
Facility Maintenance	45	7.8%
Integrated Project Delivery (IPD)	48	8.4%
Project Management	77	13.4%
Augmented reality	38	6.6%
Computer-aided facility management (CAFM)	39	6.8%
Health and Safety	37	6.4%
Green Building	54	9.4%
Construction Management Education	49	8.5%
total	574	100.0%

The major maturity level in level 1 with a percentage of 35.51% as shown in Figure (36). This result is close to other studies in the literature.

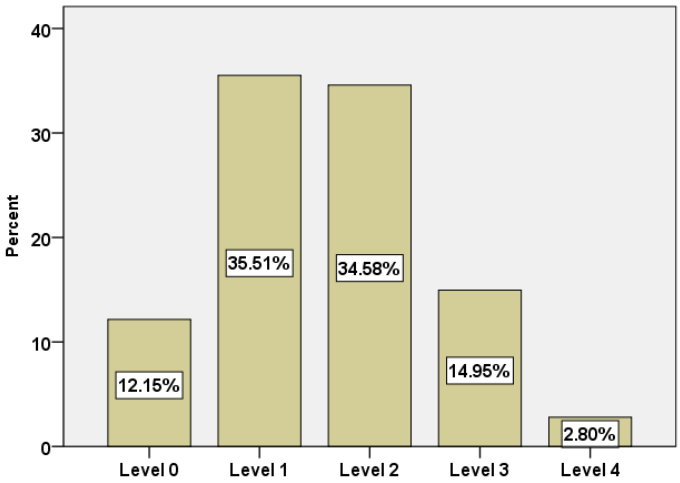

Figure 36: BIM maturity levels

The current implementing dimension of BIM is 3D, as shown in Figure (37), (69.29%).

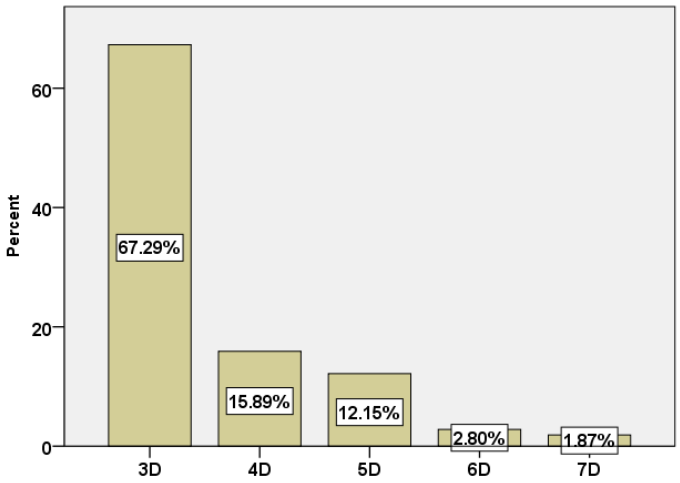

Figure 37: The current implementing Dimension of BIM in respondents' projects

Most of the respondents (70.48%), as shown in Figure (38), expected that there will be increasing use of BIM in the future. This result is in-line with the literature in KSA. However, in the other countries, the literature expected that BIM become a mandate from the governments.

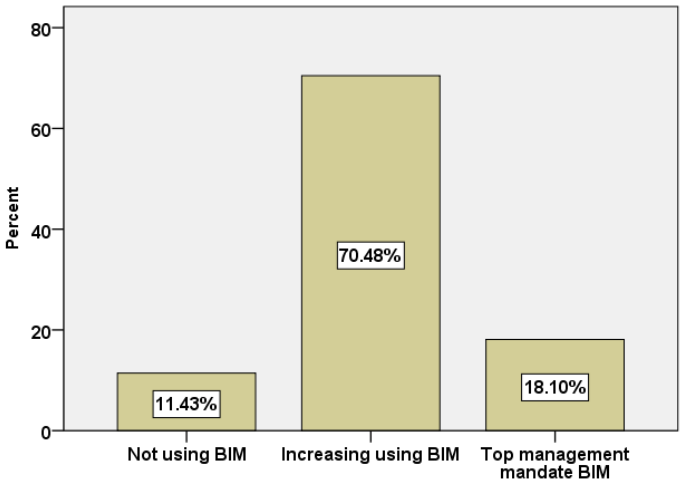

Figure 38: The future of BIM

4.1.2 Perceived benefits of BIM

4.1.2.1 Client perspective

The respondents ranked the benefits of BIM from a client perspective as illustrated in Figure (39) and Table (16).

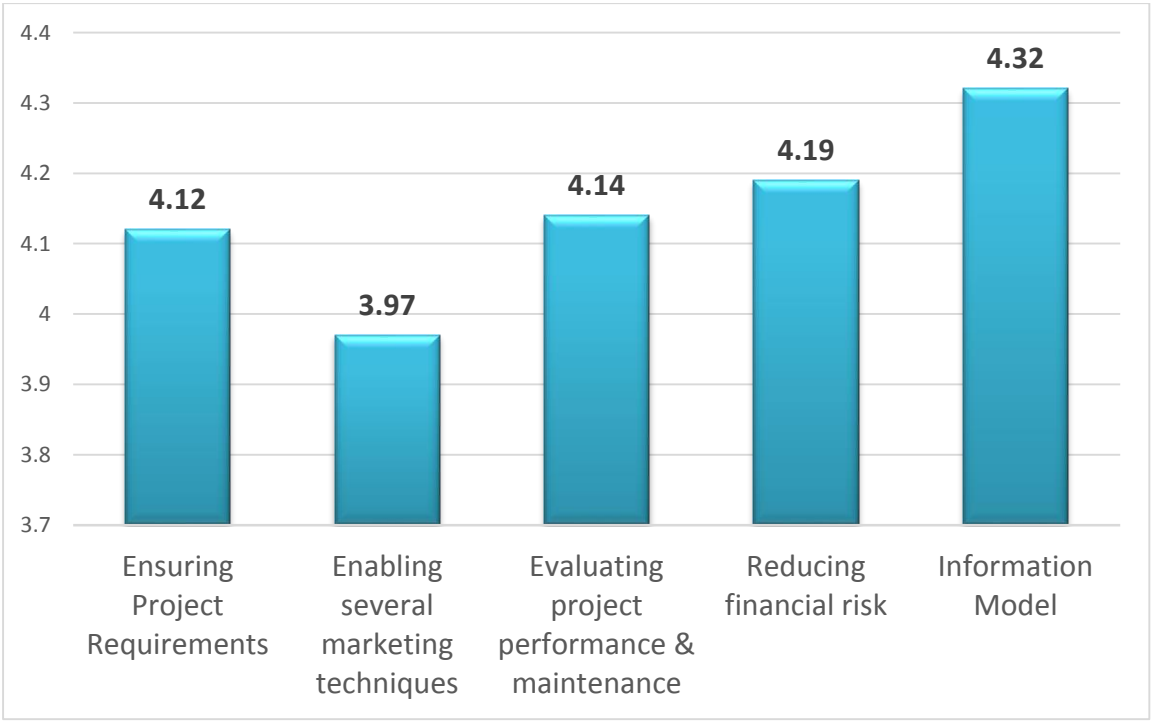

Figure 39: Benefits of BIM from Client perspective

Table 16: Benefits of BIM from Client perspective

Benefits	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	Ranking	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
Ensuring Project Requirements	3	3	14	37	41	98	4.12	.977	4	Agree
	3.1 %	3.1 %	14.3 %	37.8 %	41.8 %	100 %				
Enabling several marketing techniques	2	4	22	37	33	98	3.97	.957	5	Agree
	2 %	4.1 %	22.4 %	37.8 %	33.7 %	100 %				
Evaluating project performance & maintenance	2	4	15	34	43	98	4.14	.963	3	Agree
	2 %	4.1 %	15.3 %	34.7 %	43.9 %	100 %				
Reducing financial risk	2	6	11	31	48	98	4.19	1.002	2	Agree
	2.0 %	6.1 %	11.2 %	31.6 %	49.0 %	100 %				
Information Model	1	5	8	32	52	98	4.32	.904	1	Strongly agree
	1.0 %	5.1 %	8.2 %	32.7 %	53.1 %	100 %				
Weighted mean							4.148			Agree

Respondents reported the following benefits of BIM from clients' perspectives: time-saving, complete on time, minimizing coordination problems, improve quality, assure comparing apple to apple during the tender stage, well organize and systematic, improve company strategy, earlier involvement of client in the design stage, reducing cost.

Furthermore, one respondent reported that BIM from the client perspective is very necessary for the planning and implementation of projects, but from the beginning of the project and not after the start of implementation because it is impeding the progress of the project.

4.1.2.2 Designer perspective

The respondents claimed the benefits of BIM from designer perspective are facilitating visual evacuation plans, enabling sustainable analysis, producing various design options and extracting fast IFC drawings respectively (Figure 40 and Table 17).

Respondents reported, also, other Benefits of BIM from the designer perspective as follows: increase experience, quick review, and changes at the perfect time, coordination, avoid clashes and errors, sharing information, quick quantities take off. Those benefits are stipulated in literature but are not classified under designer perspective. The literature mentioned these benefits in general for all project parties.

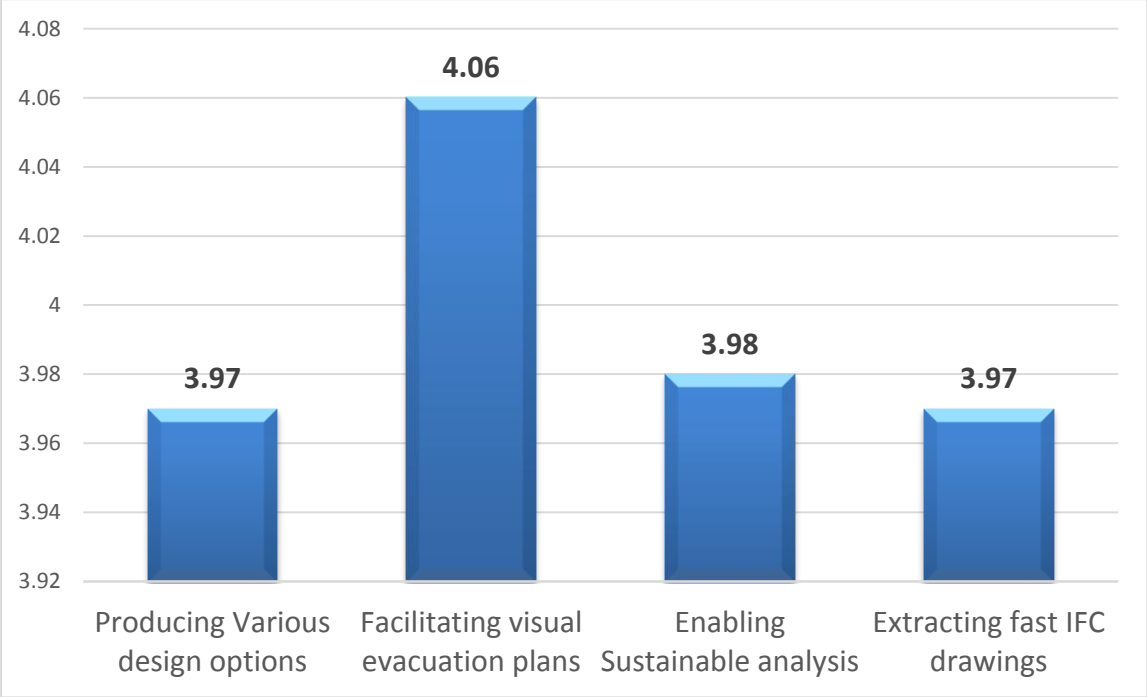

Figure 40: Benefits of BIM from Designer perspective

Table 17: Benefits of BIM from Designer perspective

Benefits	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	Ranking	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
Producing Various design options	2	14	18	47	48	129	3.97	1.045	3	Agree
	1.6 %	10.9 %	14.0 %	36.4 %	37.2 %	100 %				
Facilitating visual evacuation plans	2	4	20	61	42	129	4.06	.864	1	Agree
	1.6 %	3.1 %	15.5 %	47.3 %	32.6 %	100 %				
Enabling Sustainable analysis	3	5	30	45	46	129	3.98	.980	2	Agree
	2.3 %	3.9 %	23.3 %	34.9 %	35.7 %	100 %				
Extracting fast IFC drawings	2	3	17	49	58	129	3.97	1.045	3	Agree
	1.6 %	2.3 %	13.2 %	38.0 %	45 %	100 %				
Weighted mean							3.995			Agree

4.1.2.3 Contractor perspective

The respondents ordered the benefits from the contractor perspective as enable 3D coordination, information integration, accurate BOQ & cost estimation, supporting construction and project management, site utilizing planning, monitor & control progress, enhanced ability to compete, automated assembly, increase health & safety, and staff recruitment and retention (Figure 41 and Table 18).

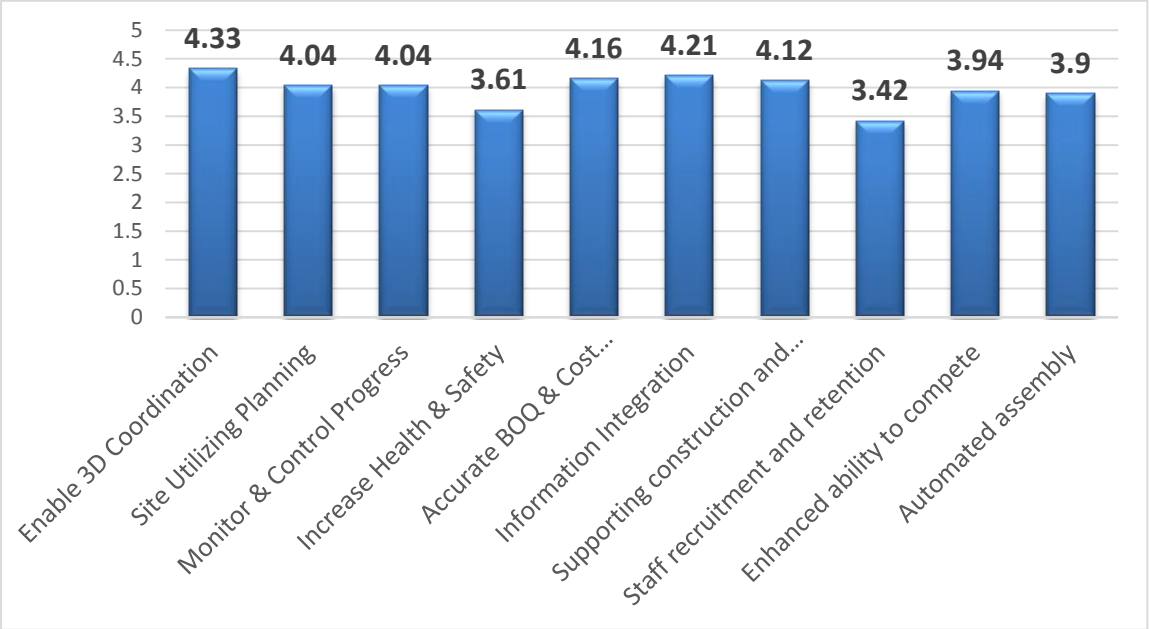

Figure 41: Benefits of BIM from Contractor perspective

Table 18: Benefits of BIM from Contractor perspective

Benefits	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	Ranking	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
Enable 3D Coordination	3	6	18	37	89	153	4.33	.965	1	Strongly agree
	2 %	3.9 %	11.8 %	24.2 %	58.2 %	100 %				
Site Utilizing Planning	3	8	30	51	61	153	4.04	.993	5	Agree
	2	5.2 %	19.6 %	33.3 %	39.9 %	100 %				
Monitor & Control Progress	3	3	36	54	57	153	4.04	.931	5	Agree
	2 %	2 %	23.5 %	35.3 %	37.3 %	100 %				
Increase Health & Safety	5	14	54	42	38	153	3.61	1.058	8	Agree
	3.3 %	9.2 %	35.3 %	27.5 %	24.8 %	100 %				
Accurate BOQ & Cost Estimation	4	8	20	49	72	153	4.16	1.014	3	Agree
	2.6 %	5.2 %	13.1 %	32.0 %	47.1 %	100 %				
Information Integration	5	6	17	49	76	153	4.21	1.011	2	Strongly agree
	3.3 %	3.9 %	11.1 %	32.0 %	49.7 %	100 %				
Supporting construction and project management	3	9	24	47	70	153	4.12	1.009	4	Agree
	2 %	5.9 %	15.7 %	30.7 %	45.8 %	100 %				

Table 18 continue: Benefits of BIM from Contractor Perspective

Benefits	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	Ranking	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
Staff recruitment and retention	10	18	55	37	33	153	3.42	1.145	9	Agree
	6.5 %	11.80 %	35.9 %	24.2 %	21.60 %	100 %				
Enhanced ability to compete	5	10	27	58	53	153	3.94	1.040	6	Agree
	3.3 %	6.5 %	17.6 %	37.9 %	34.60 %	100 %				
Automated assembly	5	9	33	56	50	153	3.90	1.033	7	Agree
	3.3 %	5.9 %	21.6 %	36.6 %	32.7 %	100 %				
Weighted mean							3.977			Agree

Respondents reported other benefits of BIM from contractors' perspective: advanced coordination, cost savings, gives a clear vision help in planning, control of cost and budget, discover conflicts and detect clashes, accurate inventory, fewer clashes on site, facility management, increase productivity and collaboration of all stakeholders.

One respondent concluded that BIM provides excellent coordination, good presentation, predict issues before the occurrence. Furthermore, another respondent pointed that BIM enhances bid accuracy with model-based estimation and improved coordination with schedule visualization. Comparing this result against the literature shows that they are similar.

4.1.2.4 Shared benefits (to all participants)

The respondents ordered the shared BIM benefits as: clash detection, time savings, improving the quality and reduced rework, increasing efficiency, enhance collaboration & communication, cost reduction, creation and sharing of information ability, data lifecycle, reduced document errors and omissions, improves visualization, reduced number of requests for information, reduced change orders, reduce waste and value generation, reduced claim and law issues (Table 19 and Figure 42).

Table 19: Benefits of BIM to all participants (shared between client, designer and contractor)

Benefits	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	order	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
Time savings	5	9	12	51	76	153	4.20	1.035	2	Agree
	3.3 %	5.90 %	7.80 %	33.3 %	49.7 %	100 %				
The cost reduction	6	10	15	51	71	153	4.12	1.082	5	Agree
	3.90 %	6.50 %	9.80 %	33.3 %	46.4 %	100 %				
Improving the quality and Reduced Rework	8	4	14	52	75	153	4.19	1.062	3	Agree
	5.2 %	2.60 %	9.20 %	34.0 %	49 %	100 %				
Clash detection	6	9	12	33	93	153	4.29	1.094	1	Strongly agree
	3.90 %	5.90 %	7.80 %	21.6 %	60.8 %	100 %				
Improves visualization	7	10	15	56	65	153	4.06	1.096	7	Agree
	4.6 %	6.50 %	9.8 %	36.6 %	42.5 %	100 %				
Reduced Number of requests for information	7	10	15	56	65	153	4.06	1.096	7	Agree
	4.6 %	6.50 %	9.8 %	36.6 %	42.5 %	100 %				
Reduced change orders	7	10	15	56	65	153	4.06	1.096	7	Agree
	4.6 %	6.50 %	9.8 %	36.6 %	42.5 %	100 %				

Table 19 continue: Benefits of BIM to all participants (shared between client, designer and contractor)

Benefits	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	order	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
Enhance collaboration & communication	5	8	17	50	73	153	4.16	1.035	4	Agree
	3.3 %	5.2 %	11.1 %	32.7 %	47.7 %	100 %				
Reduced Document Errors and omissions	6	8	17	55	67	153	4.10	1.052	6	Agree
	3.9 %	5.2 %	11.1 %	35.9 %	43.8 %	100 %				
Reduced claim and law issues	4	12	33	51	53	153	3.90	1.052	9	Agree
	2.6 %	7.8 %	21.8 %	33.3 %	34.60 %	100 %				
Reduce Waste and value generation	6	11	24	51	61	153	3.98	1.097	8	Agree
	3.9 %	7.2 %	15.7 %	33.3 %	39.9 %	100 %				
Increasing efficiency	4	12	12	48	77	153	4.19	1.050	3	Agree
	2.6 %	7.8 %	7.8 %	31.4 %	50.3 %	100 %				
Creation and sharing of information ability: Life cycle data	7	7	21	44	74	153	4.12	1.100	5	Agree
	4.6 %	4.6 %	13.7 %	28.8 %	48.4 %	100 %				
Weighted mean							4.11			Agree

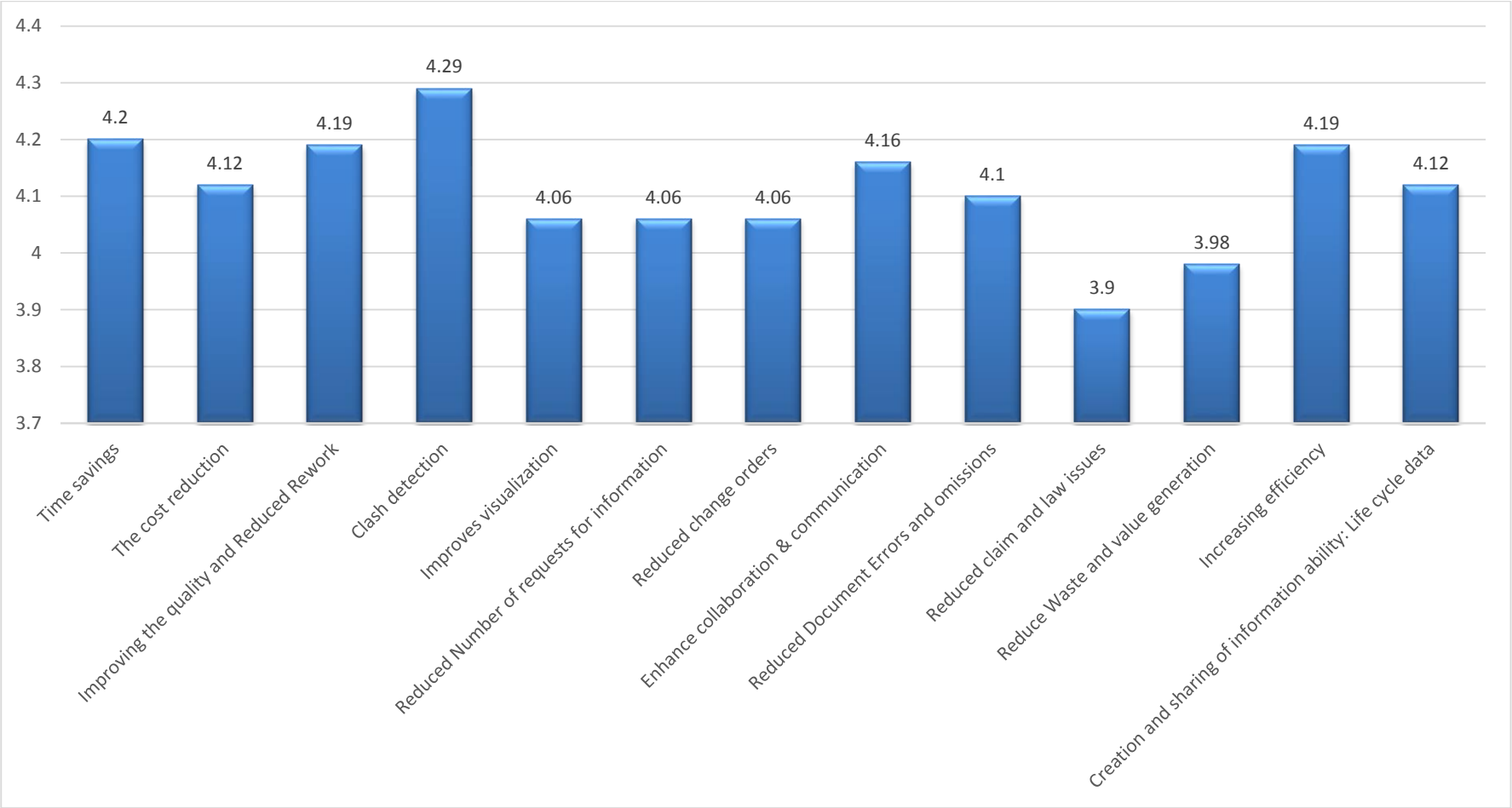

Figure 42: Benefits of BIM to all participants (shared between client, designer and contractor)

Figure (43), shows the benefits to all project parties with the highest benefit is reported to the client. This result is closed to what (Eastman, et al., 2008) claimed.

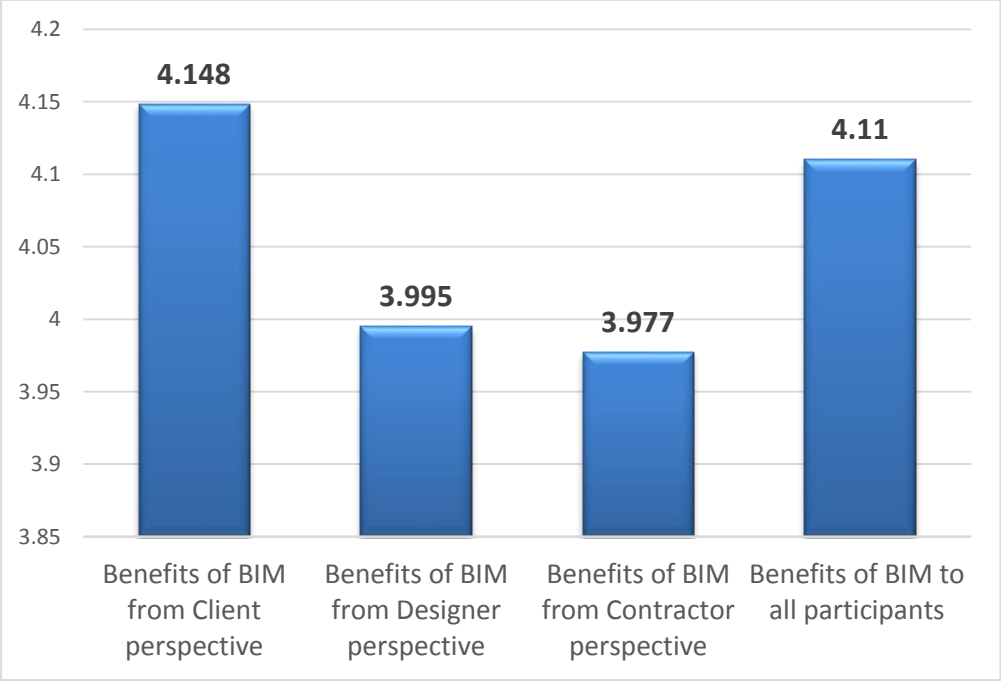

Figure 43: Perceived benefits of BIM

4.1.3 Identified the Barriers

Respondents reported that change management is the primary issue/barrier as well as the lack of competency. However, another said that the major barrier is lack of people convincing the client about it. On the other hand, one respondent claimed that the main barrier is the government did not impose to use BIM as mandatory.

4.1.3.1 Personal Barriers

The respondents ordered the personal barriers as lack of understanding of BIM and its benefits, resistance to change, lack of skills development, lack of BIM education and lack of insufficient training (Table 20 and Figure 44).

Table 20: Personal Barriers

Barriers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	Ranking	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
Lack of insufficient training	6	11	27	50	59	153	3.95	1.099	4	Agree
	3.9 %	7.2 %	17.6 %	32.7 %	38.6 %	100 %				
Lack of understanding of BIM and its benefits	5	9	22	50	67	153	4.08	1.055	1	Agree
	3.3 %	5.9 %	14.4 %	32.7 %	43.8 %	100 %				
Resistance to change: Lack of skills development	5	7	17	65	59	153	4.08	.986	1	Agree
	3.3 %	4.6 %	11.1 %	42.5 %	38.6 %	100 %				
Lack of BIM education	6	13	22	51	61	153	3.97	1.115	3	Agree
	3.3 %	8.5 %	14.4 %	33.3 %	39.9 %	100 %				
Lack of BIM knowledge in applying current technologies	6	8	24	48	67	153	4.06	1.077	2	Agree
	3.9 %	5.2 %	15.7 %	31.4 %	43.8 %	100 %				
Weighted mean							4.028			Agree

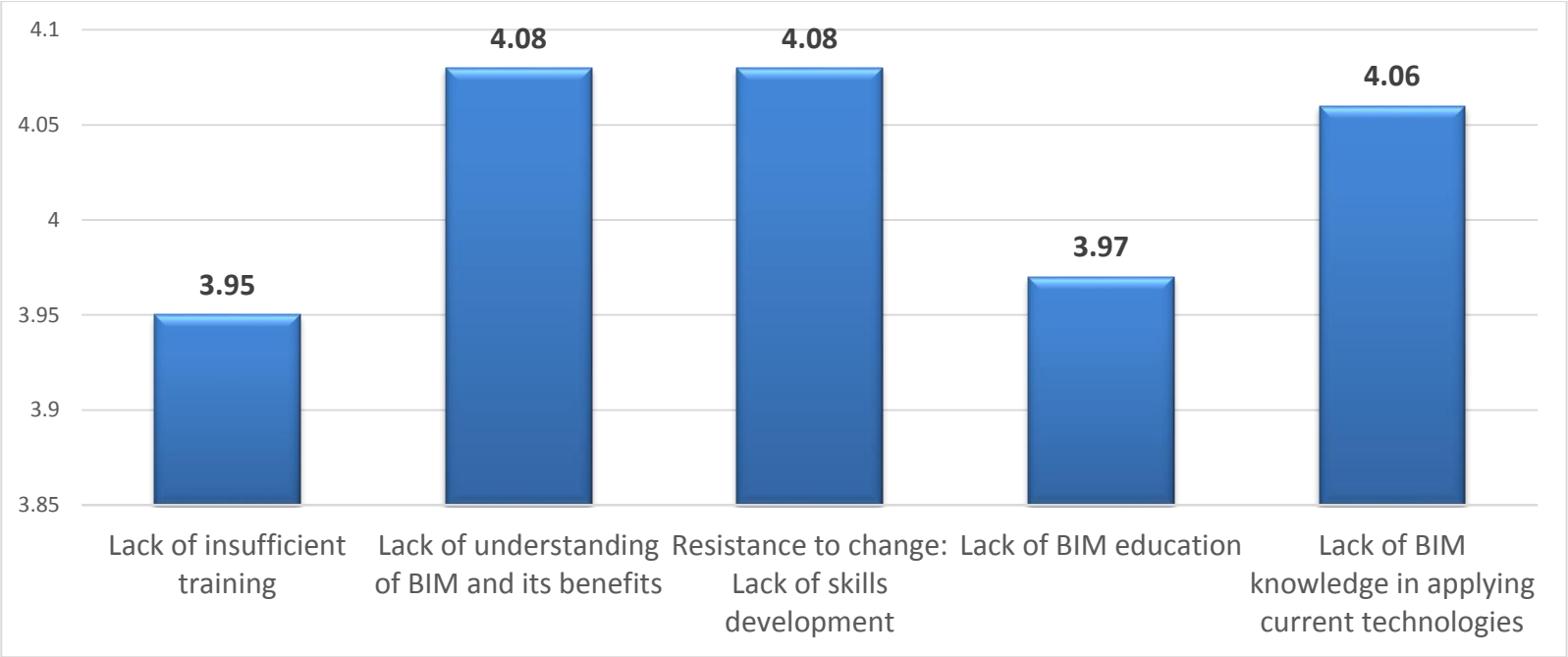

Figure 44: Personal Barriers

Also respondents reported that the personal barriers could be cultural issues, most of the people are involved in a construction area are afraid to share their data for lack of mutual trust and other reasons, lack of advertisement in magazine and news on TV, insufficient fund, shared risk-reward, and lack of conduct long-term relationships.

One respondent reported that “I am concerned that BIM designers do not have enough real field experience to be able to design in a way that can be built cost effectively and safely. Explained another way just because it can be built on a computer screen does not mean it can be built in the field.”

4.1.3.2 Process Barriers

The respondents claimed the ordered of process barriers as changing work processes, lack of effective collaboration among project participants, risks, and challenges with the use of a single model BIM, legal issues (Figure 45 and Table 21).

Also, respondents reported that the process barriers can be of low maturity level, software licenses cost, confidential information. Literature does not mention these results.

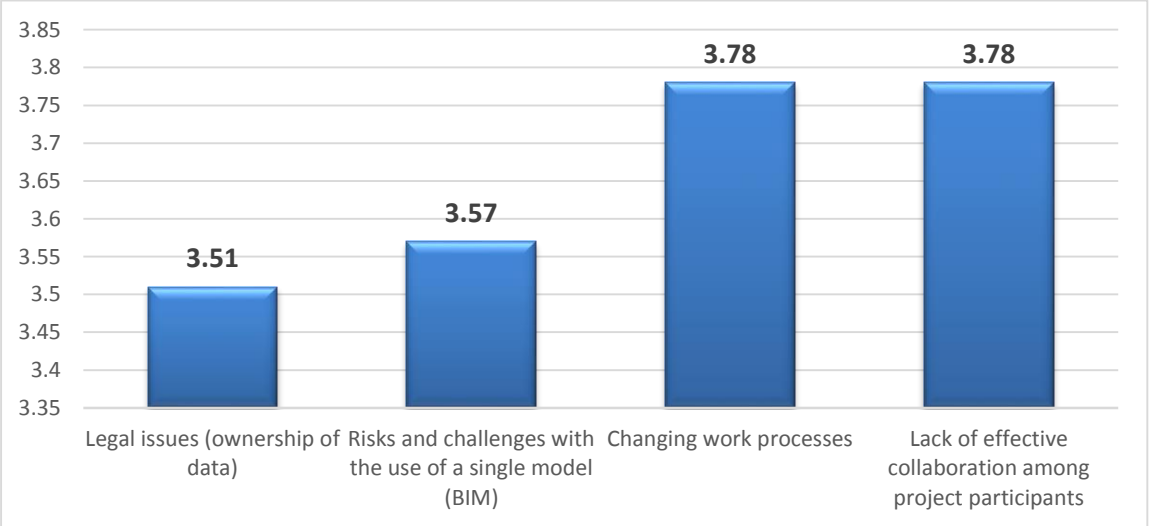

Figure 45: BIM Process Barriers

Table 21: BIM Process Barriers

Barriers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	Ranking	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
Legal issues (ownership of data)	6	15	56	47	29	153	3.51	1.033	3	Agree
	3.9 %	9.8 %	36.6 %	30.7 %	19 %	100 %				
Risks and challenges with the use of a single model (BIM)	5	17	47	54	30	153	3.57	1.031	2	Agree
	3.3 %	11.1 %	30.7 %	35.3 %	19.6 %	100 %				
Changing work processes	5	11	38	57	42	153	3.78	1.032	1	Agree
	3.3 %	7.2 %	24.8 %	37.3 %	27.5 %	100 %				
Lack of effective collaboration among project participants	5	11	38	57	42	153	3.78	1.032	1	Agree
	3.3 %	7.2 %	24.8 %	37.3 %	27.5 %	100 %				
Weighted mean							3.66			Agree

4.1.3.3 Business Barriers

Time and cost of training, lack of contractual arrangements, complicated and time-consuming modelling process, doubts about return on investment, the high cost of implementation, and unclear benefits reported as respondents' business barriers (Figure 46 and Table 22).

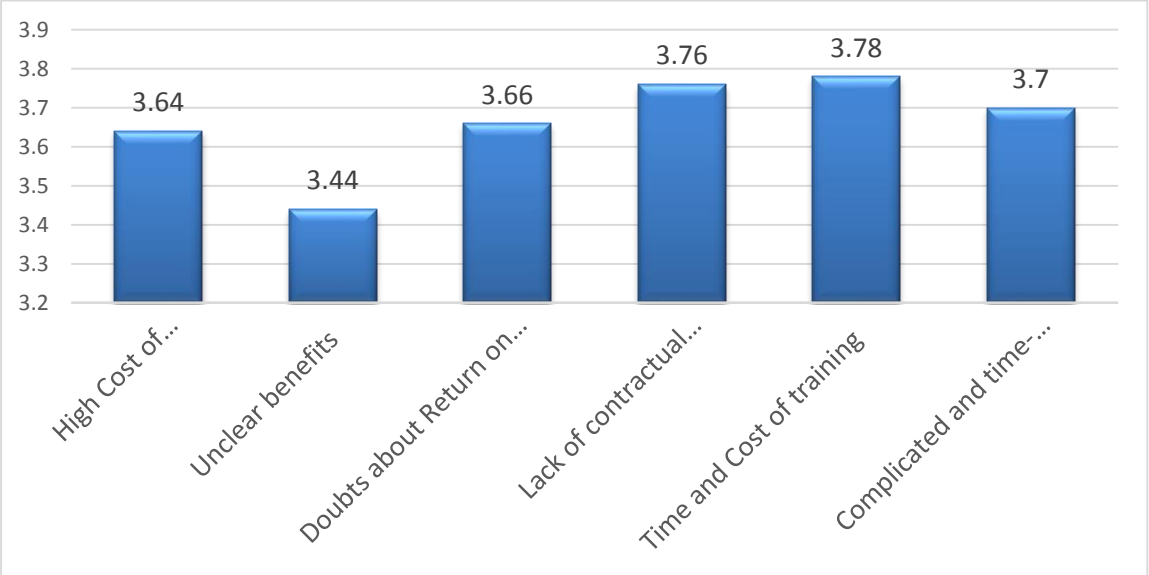

Figure 46: Business Barriers

Table 22: Business Barriers

Barriers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	Ranking	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
High Cost of implementation	8	18	27	68	32	153	3.64	1.098	5	Agree
	5.2 %	11.8 %	17.6 %	44.4 %	20.9 %	100 %				
Unclear benefits	8	27	38	50	30	153	3.44	1.146	6	Agree
	5.2 %	17.6 %	24.8 %	32.7 %	19.0 %	100 %				
Doubts about Return on Investment	5	14	40	63	31	153	3.66	1.008	4	Agree
	3.3 %	9.2 %	26.1 %	41.2 %	20.3 %	100 %				
Lack of contractual arrangements	6	8	42	58	39	153	3.76	1.020	2	Agree
	3.9 %	5.2 %	27.5 %	37.9 %	25.5 %	100 %				
Time and Cost of training	8	7	34	65	39	153	3.78	1.045	1	Agree
	5.2 %	4.6 %	22.2 %	42.5 %	25.5 %	100 %				
Complicated and time-consuming modelling process	8	19	26	58	42	153	3.70	1.153	3	Agree
	5.2 %	12.4 %	17 %	37.9 %	27.5 %	100 %				
Weighted mean							3.663			Agree

4.1.3.4 Technical Barriers

The respondents concluded technical barriers as the lack of BIM technical experts, the absence of standards and clear guidelines, insufficient technology infrastructure, insufficient interoperability, and the belief that current technology is enough (Figure 47 and Table 23).

Also respondents reported that technical barriers can be unfamiliar software, lack of technical support, unreachable growth, different standards from one region to another may cause difficulties when a person moves from one country to another, lack of using technology and Lack of globally standardized coding structures (i.e. Omniclass or Norsok Z-014) to enable the 3D, 4D and 5D databases to exchange data. This result does not found in the literature.

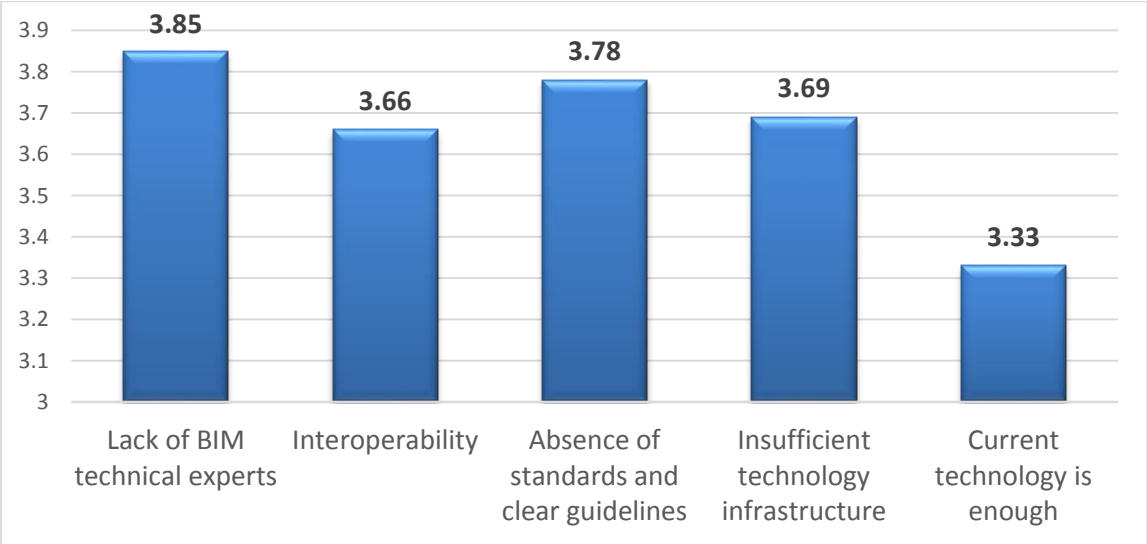

Figure 47: Technical Barriers

Table 23: Technical Barriers

barriers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	Ranking	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
Lack of BIM technical experts	9	8	28	60	48	153	3.85	1.105	1	Agree
	5.9 %	5.2 %	18.3 %	39.2 %	31.4 %	100 %				
Interoperability	8	5	52	54	34	153	3.66	1.027	4	Agree
	5.2 %	3.3 %	34 %	35.3 %	22.2 %	100 %				
Absence of standards and clear guidelines	8	9	33	61	42	153	3.78	1.076	2	Agree
	5.2 %	5.9 %	21.6 %	39.9 %	27.5 %	100 %				
Insufficient technology infrastructure	8	14	34	59	38	153	3.69	1.103	3	Agree
	5.2 %	9.2 %	22.2 %	38.6 %	24.8 %	100 %				
Current technology is enough	14	28	35	46	30	153	3.33	1.240	5	Neutral
	9.2 %	18.3 %	22.9 %	30.1 %	19.60 %	100 %				
Weighted mean							3.662			Agree

4.1.3.5 Organization Barriers

The respondents reported the order of organization barriers as the lack of senior management support, unwillingness to change, difficulties in managing the impacts of BIM, the magnitude of change/staff turnover, the absence of other competing initiatives, and construction insurance (figure 48 and table 24).

Also, respondents reported that the organization barriers can be company policy, coordination is in futile, top management experience, competency, and leadership.

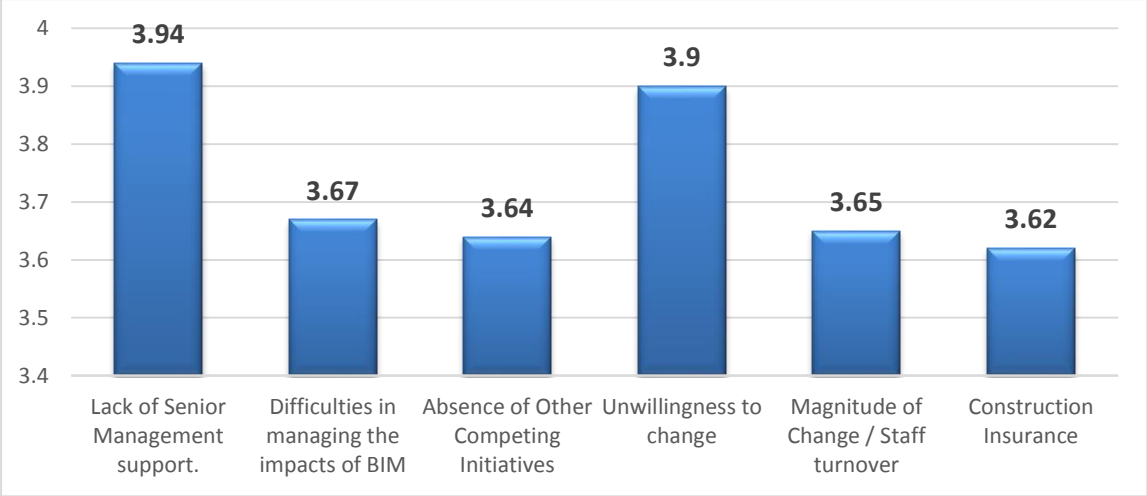

Figure 48: Organization Barriers

Table 24: Organization Barriers

Barriers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	Ranking	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
Lack of Senior Management support	8	8	27	52	58	153	3.94	1.114	1	Agree
	5.2 %	5..2 %	17.6 %	34.0 %	37.9	100 %				
Difficulties in managing the impacts of BIM	8	12	41	54	38	153	3.67	1.094	3	Agree
	5.2 %	7.8 %	26.8 %	35.3 %	24.8 %	100 %				
Absence of Other Competing Initiatives	6	9	57	43	38	153	3.64	1.043	5	Agree
	3.9 %	5.9 %	37.3 %	28.1 %	24.8 %	100 %				
Unwillingness to change	6	12	29	51	55	153	3.90	1.101	2	Agree
	3.90 %	7.8 %	19 %	33.3 %	35.9 %	100 %				
Magnitude of Change / Staff turnover	9	12	43	49	40	153	3.65	1.127	4	Agree
	5.9 %	7.8 %	28.1 %	32 %	26.1 %	100 %				
Construction Insurance	9	14	46	41	43	153	3.62	1.159	6	Agree
	5.9 %	9.2 %	30.1 %	26.8 %	28.1 %	100 %				
Weighted mean							3.7366			Agree

4.1.3.6 Market Barrier

The respondents reported that market barriers included lack of publicity and awareness and lack of client/government demand (Figure 49 and Table 25). The literature added the market is not ready yet, however, the respondents claimed that the market is ready.

Also, respondents reported that the market barriers can be low realized benefits, understanding the importance of BIM, and competency as well as lack of stewardship.

One respondent reported that “no incentive for anyone to deal with life-cycle as people will be dead! And Attention must be paid to marketing BIM. There are no market barriers if management, marketing, and good publicity are available.

Figure (50), shows that the most frequent barriers come from the personal side.

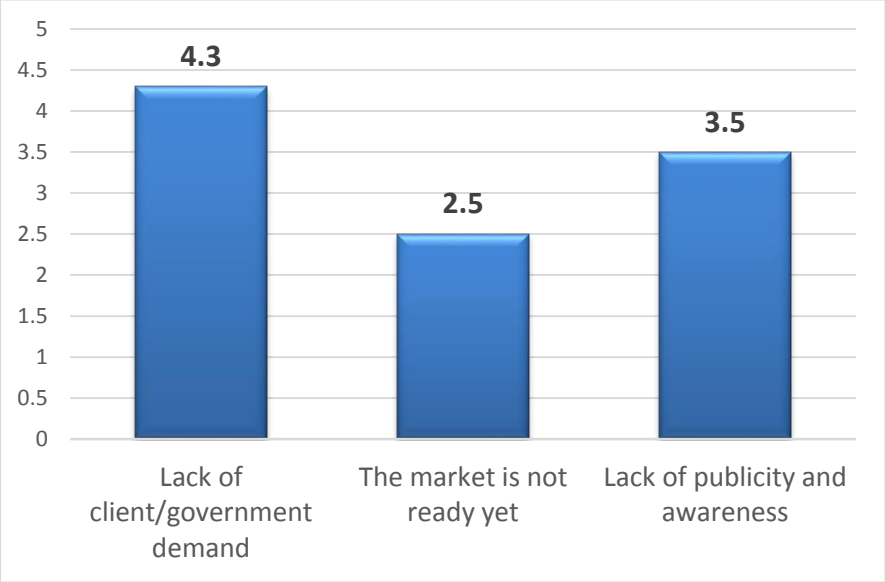

Figure 49: Market Barriers

Table 25: Market Barriers

Barriers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	Ranking	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
Lack of client/government demand	8	16	27	49	53	153	3.80	1.176	1	Agree
	5.2 %	10.5 %	17.6 %	32.0 %	34.6 %	100 %				
The market is not ready yet	12	32	38	37	34	153	3.32	1.249	0	Neutral
	7.8 %	20.9 %	24.8 %	24.2 %	22.2 %	100 %				
Lack of publicity and awareness	7	16	23	65	42	153	3.78	1.102	2	Agree
	4.6 %	10.5 %	15.0 %	42.5 %	27.5 %	100 %				
Weighted mean							3.633			Agree

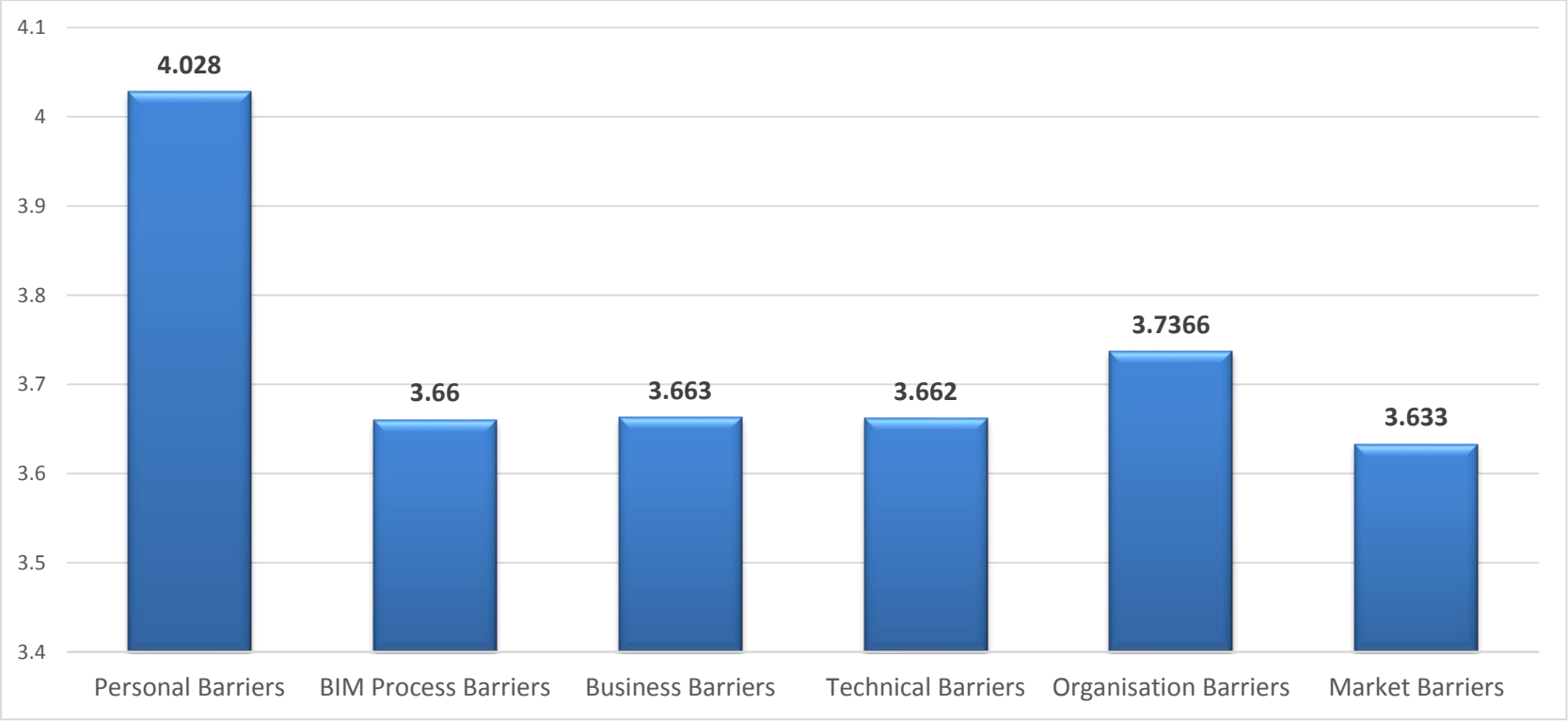

Figure 50: The barriers to implementing BIM in KSA

4.1.4 Key Factors influence the adoption

4.1.4.1 External Push

The respondents claimed that in order to push implementing BIM; the following are required: (1) providing guidance on use of BIM,(2) government support and pressure in the implementation of BIM, (3) provide education at university level, (4) developing BIM data exchange standards, (5) rules and regulations, (6) perceived benefits from BIM to client, (7) collaboration with universities (research collaboration and curriculum design for students), (8) BIM required by other project parties, (9) client pressure and demand the application of BIM in their projects, (10) clients provide pilot project for BIM, (10) contractual arrangements, (11) promotion and awareness of BIM, and (12) competitive pressure (Table 26 and Figure 51). Additionally, one of the respondents said that other external push can sponsor events like BIM Saudi day.

Table 26: External Push for Implementing BIM in KSA

Key Factors	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	Ranking	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
Government support and pressure in the implementation of BIM	10	14	17	40	72	153	3.98	1.243	2	Agree
	6.5 %	9.2 %	11.1 %	26.1 %	47.1 %	100 %				
Client pressure and demand the application of BIM in their projects	9	10	23	50	62	153	3.95	1.160	5	Agree
	5.9 %	6.5 %	14.4 %	32.7 %	40.5 %	100 %				
Provide education at university level	6	8	30	48	61	153	3.98	1.079	2	Agree
	3.9 %	5.2 %	19.6 %	31.4 %	39.9 %	100 %				
Developing BIM data exchange standards, rules and regulations	8	5	32	47	61	153	3.97	1.103	3	Agree
	5.2 %	3.3 %	20.9 %	30.7 %	39.9 %	100 %				
Providing guidance on use of BIM	9	5	20	60	59	153	4.01	1.088	1	Agree
	5.9 %	3.3 %	13.1 %	39.2 %	38.6 %	100 %				
contractual arrangements	9	3	30	60	51	153	3.92	1.067	7	Agree
	5.9 %	2 %	19.6 %	39.2 %	33.3 %	100 %				

Table 26 continues: External Push for Implementing BIM in KSA

Key Factors	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	Ranking	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
BIM required by other project parties	8	4	31	53	57	153	3.96	1.075	4	Agree
	5.2 %	2.6 %	20.3 %	34.6 %	37.3 %	100 %				
Competitive pressure	10	4	34	57	48	153	3.84	1.101	9	Agree
	6.5 %	2.6 %	22.2 %	37.3 %	31.4 %	100 %				
Promotion and awareness of BIM	7	5	37	51	53	153	3.90	1.062	8	Agree
	4.6 %	3.3 %	24.2 %	33.3 %	34.6 %	100 %				
Clients provide pilot project for BIM	7	5	30	60	51	153	3.93	1.037	6	Agree
	4.6 %	3.3 %	19.6 %	39.2 %	33.3 %	100 %				
Collaboration with universities (Research collaboration and curriculum design for students)	8	5	30	52	58	153	3.96	1.088	4	Agree
	5.2 %	3.3 %	19.6 %	34.0 %	37.9 %	100 %				
Perceived benefits from BIM to client	8	2	33	54	56	153	3.97	1.054	3	Agree
	5.3 %	1.3 %	21.6 %	35.3 %	36.6 %	100 %				
Weighted mean							3.9475			Agree

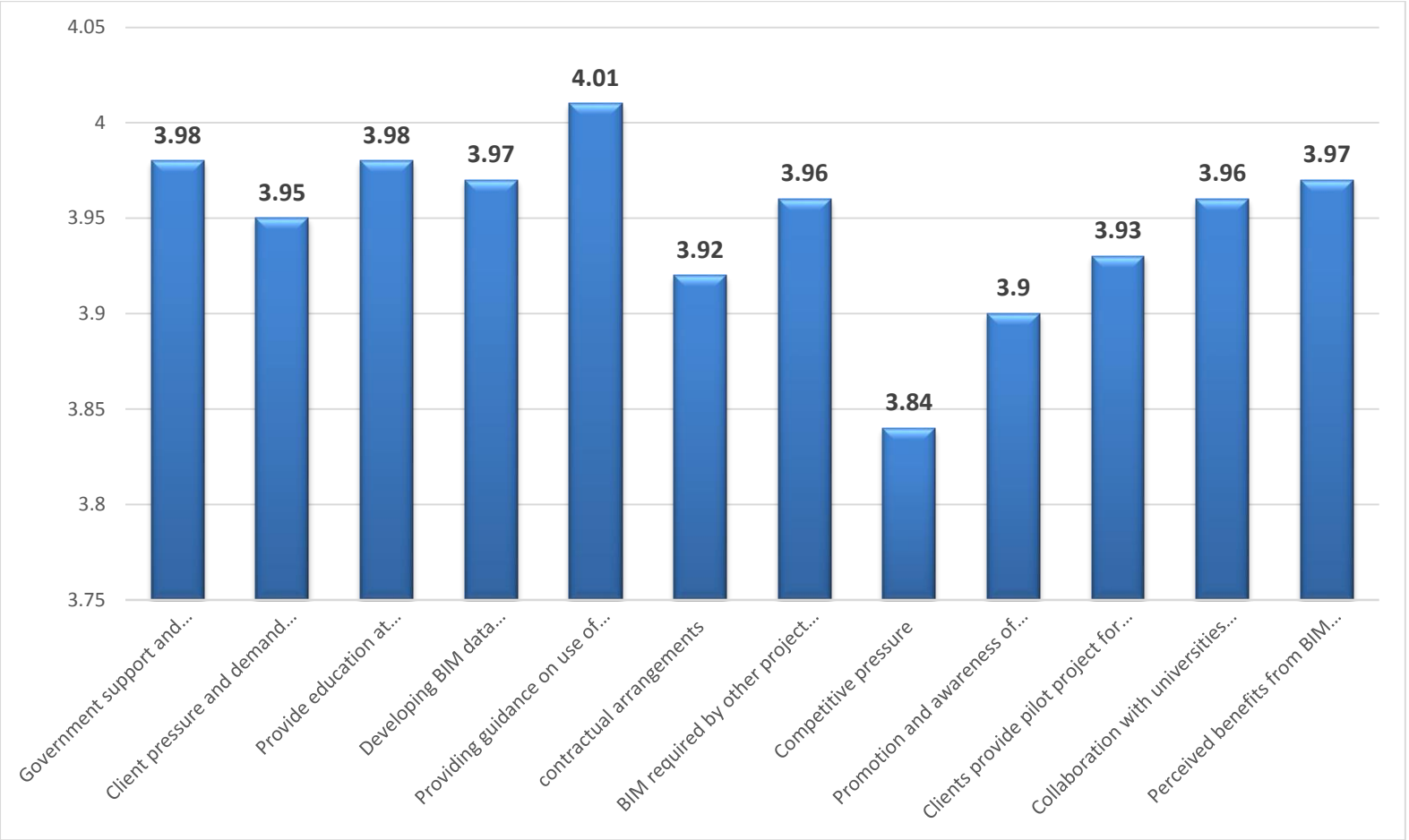

Figure 51: External Push for Implementing BIM in KSA

4.1.4.2 Internal Push

(Table 27 and Figure 52) explain respondents' factors representing the internal push for BIM implementation as: (1) top management support, (2) cultural change, (3) perceived benefits from BIM, (4) BIM training program to staff, (5) improving built output quality,(6) continuous investment in BIM, (7) desire for innovation with competitive advantages and differentiation in the market, (8) technical competence of staff, (9) financial resources of organization, (10) requirement for staff to be BIM competent, (11) improving the capacity to provide whole-life value to client, and (12) safety into the construction process (reduce risk of accident).

Additionally, other internal push reported: encouragement from all stakeholders and understanding how BIM will add value to the procurement process.

Table 27: Internal Push for Implementing BIM in KSA

Key Factors	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	Ranking	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
Top management support	7	4	24	49	69	153	4.10	1.059	1	Agree
	4.6 %	2.6 %	15.7 %	32.0 %	45.1 %	100 %				
Cultural change	7	4	24	55	63	153	4.07	1.043	2	Agree
	4.6 %	2.6 %	15.7 %	35.9 %	41.2 %	100 %				
Improving built output quality	7	4	22	63	57	153	4.04	1.019	3	Agree
	4.6 %	2.6 %	14.4 %	41.2 %	37.3 %	100 %				
Perceived benefits from BIM	6	3	22	65	57	153	4.07	.974	2	Agree
	3.9 %	2 %	14..4 %	42.5 %	37.3 %	100 %				
Technical competence of staff	8	4	24	66	51	153	3.97	1.035	5	Agree
	5.2 %	2.6 %	15.7 %	43.1 %	33.3 %	100 %				
Financial resources of organization	6	5	28	64	50	153	3.96	.999	6	Agree
	3.9 %	3.3 %	18.3 %	41.8 %	32.7 %	100 %				

Table 27 continues: Internal Push for Implementing BIM in KSA

Key Factors	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	Ranking	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
Desire for innovation with competitive advantages and differentiation in the market.	5	5	33	57	53	153	3.97	.996	5	Agree
	3.3 %	3.3 %	21.6 %	37.3 %	34.6 %	100 %				
Improving the capacity to provide whole-life value to client	6	5	34	59	49	153	3.92	1.013	8	Agree
	3.9 %	3.3 %	22.2 %	38.6 %	32.0 %	100 %				
Safety into the construction process (reduce risk of accident)	7	11	35	63	37	153	3.73	1.051	9	Agree
	4.6 %	7.2 %	22.9 %	41.2 %	24.2 %	100 %				
BIM training program to staff	7	2	24	61	59	153	4.07	1.004	2	Agree
	4.6 %	1.3 %	15.7 %	39.9 %	38.6 %	100 %				
Requirement for staff to be BIM competent	6	6	29	62	50	153	3.94	1.015	7	Agree
	3.9 %	3.9 %	19 %	40.5 %	32.7 %	100 %				
Continuous investment in BIM	7	3	28	62	53	153	3.99	1.013	4	Agree
	4.6 %	2 %	18.3 %	40.5 %	34.6 %	100 %				
Weighted mean							3.9858			Agree

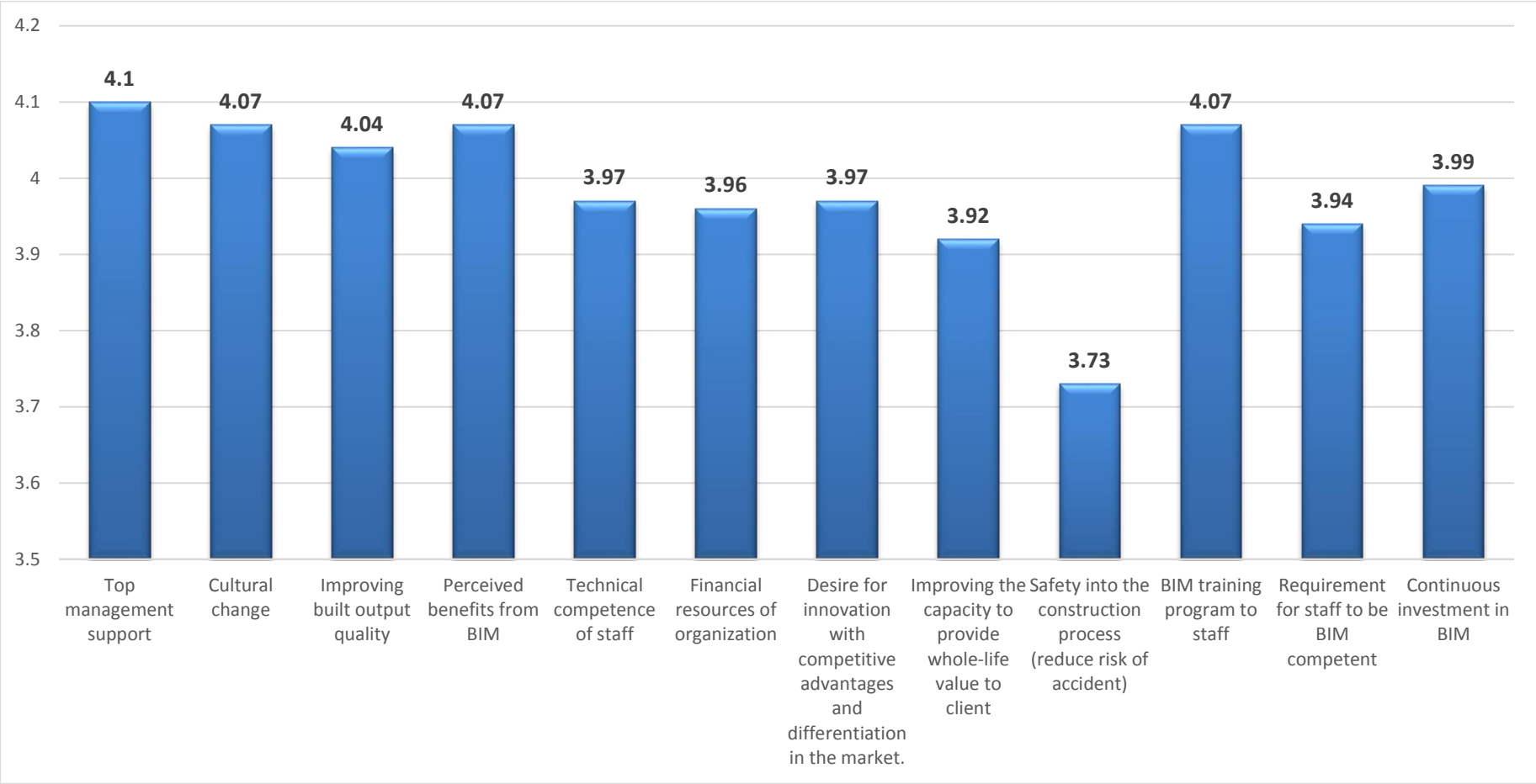

Figure 52: Internal Push for Implementing BIM in KSA

Figure (53) shows a small difference between internal and external pushes to implement BIM. We drive from this study a confirmation to a combination between the top-down and bottom-up approaches.

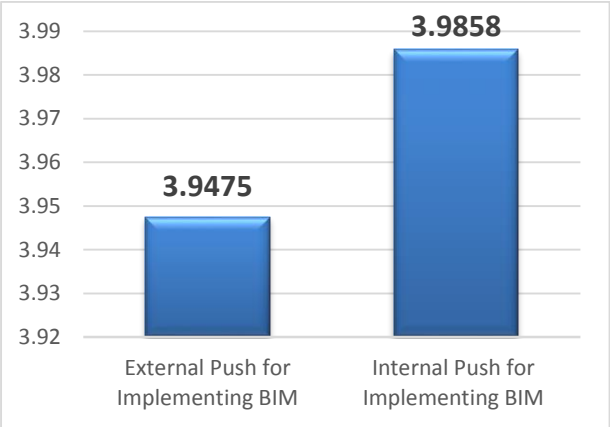

Figure 53: Key Factors influence the implementation of BIM

The respondents ordered the main factors influence the BIM implementation are as follows: push factors, perceived benefits of BIM and barriers that hindered implementing BIM (Table 28 and Figure 54).

Table 28: Key Factors influence the implementation of BIM

Factors influence the BIM implementation	Weighted mean	Rank
Push factors	4.46665	1
Perceived benefits of BIM	4.0715	2
Barriers & obstacles	3.844	3

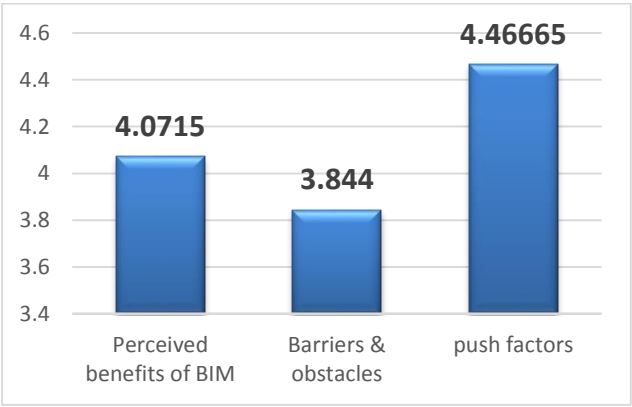

Figure 54: Factors influence the BIM implementation

Table (29), claimed non-BIM users' respondents intend to use BIM due to its perceived benefits, keep up with the latest technology; it is the future, improves their competences, and responses to the top management and the client demands.

Table 29: Coding the responses why BIM non-users intend to use

Reasons	Frequencies	Percent	Ranking
Perceived benefits	57	43.85%	1
It is the Future	32	24.62%	2
improve my self	31	23.85%	3
Client demand it	6	4.62%	4
Top management mandate BIM	4	3.08%	5
Total	130	100 %	

4.2 Interviews

(Löfgren, 2013) concluded the steps of qualitative analysis of interview data as; reading the transcripts, labeling relevant pieces, deciding which codes are the most important, and creating categories by bringing several codes together, labeling categories and deciding which are the most relevant and how they are connected to each other and finally writing up your results.

Interviews with 100 professionals (50 of them are BIM professionals and the other do not use BIM) arranged to enhance and validate the results of the questionnaire.

The professionals who are BIM expert provide responses for all sections, however, the BIM non-users provide only responses related to their barrier to using BIM and their opinions about the key factors leverage the implementation.

4.2.1 Raising the awareness about BIM

The interviewees agree with the research's literature about raising the awareness about BIM sections. As illustrated in the following section more interpretation for some points.

4.2.1.1 BIM definitions

There is no agreement about BIM definition, about three from 50 BIM expert interviewees provided the same definition. Everyone defined BIM according to what for and how they use BIM. The literature proved the same results. As following some interviewees' point of views:

Tom Lazear, CEO at Archway Systems and Bentley systems, said "I've been fortunate to have been involved in BIM for over 50 years. 50 years! you must be kidding. No, BIM has been around for that long. First, is the B to be treated as a verb or a noun? If it is a noun, then BIM only applies to vertical buildings. If the B is a verb, which it really should be, then BIM applies to any project in the built environment. Projects in the built environment have four metrics... Quality, Cost,

and Schedule, and for sure Safety. BIM is only useful if it contributes positively to those metrics. 50 years ago Fluor used in-house developed, mainframe software for BIM for a $1billion project for Sasol in South Africa along with a transatlantic cable for data transfer. The project cost and schedule, design information, material control, expediting, labor management for 10,000 field workers were all done.... managing the process of building with computerized information. The technology has changed since that time, but still BIM."

Eng. Hany Salah said, "There are many definitions of BIM, but the most appropriate one is that articulated by NBIMS (2010)" A digital representation of physical and functional characteristics of the facility. BIM is a shared knowledge resource of information about a facility forming a reliable basis for decisions during its lifecycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of stakeholders"

Eng. Omar Selim said, "If you ask five people about BIM definition, you will get six different answers, the definition which I follow is that BIM is a set of techniques and methods of work. BIM is a process involving the generation and management of digital representations of physical and functional characteristics of places."

4.2.1.2 BIM Maturity

Almost all interviewees reported that BIM level of maturity in KSA still trying to move from level (0) to level (1).

4.2.1.3 BIM tools

The interviewees use several BIM tools everyone uses the tools that help him to achieve this requirement. For example, Eng. Omar Selim said that Revit, Archi CAD, Vico, Bentley, Vector Works, Naviswork, Tekla Structures help him.

4.2.1.4 BIM applications

Every interviewee clarifies his perspective about BIM applications according to what BIM could respond to his demands.

Eng. Omar Selim mentioned that he uses BIM in (1) Interaction with non-professionals,(2) Design analysis,(3) Drawing production,(4) Project scheduling (programming),(5) Cost estimating,(6) Tendering,(7) Quantity Surveying,(8) Site layout planning,(9) support constructability and analysis,(10) Collaboratively created, shared, and maintained models across the project lifecycle, (11) Safety (training and education, design, planning, accident investigation, and facility and maintenance phase). However, Eng. Hany claimed that he use BIM in:(1) Material take-off, (2) Clash detection, (3) Build-in code and specifications, (4) Cost estimating, (5) Project planning and construction monitoring, (6) Sustainability analysis, (7) Virtual reality, and (8) Augmented reality.

4.2.1.5 Integration with BIM

BIM can integrate with: (1) Lean construction,(2) Geography information system (GIS),(3) Enterprise Resource Planning (ERP),(4) Virtual Reality,(5) Facility Maintenance,(6) Integrated Project Delivery (IPD),(7) Project Management,(8) Augmented reality for interactive architectural visualization,(9) Computer-aided facility management (CAFM),(10) Health and,(11) Green Building,(12) Construction Management Education,(13) Just in Time Production,(14) Total Quality Management, and (15) Six Sigma as the interviewees confirmed.

The interviewees illustrated how BIM integrated with each area, for example, Parveen Sharma, BIM/VDC/IPD specialist, said, “It's important to involve all project stakeholders in the BIM adoption process. Then only the goal of Integrated Project Delivery through will become reality.”

4.2.1.6 Future of BIM in KSA

However, most interviewees reported that the use of BIM will increase in the near future in KSA. Eng. Mohammad El Yamani, BIM manager Kemet Corp. said, “BIM is already in the market for more than 4 years. Governmental agencies like the ministry of health mandates BIM usage in many hospitals and big projects.”

4.2.2 Perceived benefits of BIM

Omar Selim said "Using BIM saves raw material for future generations"

4.2.2.1 Client perspective

Table (30) concludes the interviewees coding for benefits of BIM from the client perspective).

Table 30: Coding for benefits of BIM from Client perspective

Benefits	Ranking
Information Model	1
Reducing financial risk	2
Evaluating project performance & maintenance	3
Ensuring Project Requirements	4
Enabling several marketing techniques	5

4.2.2.2 Designer perspective

In the table (31), interviewees mention the benefits of BIM from a designer perspective.

Table 31: Coding for benefits of BIM from Designer perspective

Benefits	Ranking
Facilitating visual evacuation plans	1
Error-free design (Low redesign)	1
Clash detection	1
Enabling Sustainable analysis	2
Producing Various design options	3
Extracting fast IFC drawings	4
Collaboration between all disciplines	5
Fast decisions from the client	6
save time	7
Enhance competitions between designers	8
Broken the distance barriers	9

Eng. Selim added that BIM provides helping the decision makers to improve their knowledge concerning the development of their cities for better adaptation of their legislation for the territory development, city planning and landscaping, Faster, coast effective, Quality design production, 3D, sharing files, and quantity oriented.

The interviewee stated that due to major conflicts between different disciplines, we are thinking to integrate the BIM methodology to enhance the quality of works and to reduce work-waste.

4.2.2.3 Contractor perspective

Many interviewees reported that the contractor can reap from BIM improved productivity, boost profits making, accurate quantity take-off, foster collaboration, cut cost, save time, improve quality, less rework, enable 3D coordination, site utilizing planning, improved logistics and machinery planning. Moreover, claimed contractor benefits are: safety measures (improve safety management), accurate BOQ & cost estimation, information integration, supporting construction and project management (improved performance of the facility management (FM)), enhanced ability to compete, automated assembly (enhance Just in time to save time, cost and material), and reduction in wasted materials. The most ranked benefits as shown in the table (32).

Table 32: Coding for benefits of BIM from Contractor perspective

Benefits	Ranking
Enable 3D Coordination	1
Information Integration	2
Accurate BOQ & Cost Estimation	3
Supporting construction and project management	4
Monitor & Control Progress	5
Site Utilizing Planning	6
Enhanced ability to compete	7
Automated assembly	8
Increase Health & Safety	9
Staff recruitment and retention	10

4.2.2.4 Shared benefits (to all participants)

In table (33), interviewees explained benefits of BIM from all participants' perspective.

Table 33: Coding for benefits of BIM from all participants' perspective

Benefits	Ranking
Clash detection	1
Time savings	2
Improving the quality and Reduced Rework	3
Increasing efficiency	4
Enhance collaboration & communication	5
The cost reduction	6
Creation and sharing of information ability: Lifecycle data	7
Reduced Document Errors and omissions	8
Improves visualization	9
Reduced Number of requests for information	10
Reduced change orders	11
Reduce Waste and value generation	12
Reduced claim and law issues	13
Early client involvement	14
Improve decision making	15
Promoted the off-site prefabrication (Precast concrete- etc.)	16
meet client satisfaction	17
Reliable sustainability analysis	18
accurate production of As-Built drawings	19

Many interviewees claimed that using modern technology would help in obtaining access to reports and statistics and determination of problems and obstacles that might impede any project.

4.2.3 Identifying the barriers

4.2.3.1 Personal Barriers

Table (34), ranks the personal barriers to BIM implementation according to interviewees.

Table 34: Coding of Personal Barriers

Barriers	Ranking
Lack of understanding of BIM and its benefits	1
Lack of BIM knowledge in applying current technologies	2
Resistance to change: Lack of skills development	3
Lack of BIM education	4
Lack of insufficient training	5

4.2.3.2 Process Barriers

Table (35), ranks process barriers for implementing BIM according to interviewees.

Table 35: Coding of Process Barriers

Barriers	Ranking
Changing work processes	1
Lack of effective collaboration among project participants	2
Risks and challenges with the use of a single model (BIM)	3
Legal issues (ownership of data)	4

4.2.3.3 Business Barriers

Table (36), highlights business barriers from interviewees 'point of view.

Table 36: Coding of Business Barriers

Barriers	Ranking
Time and Cost of training	1
Lack of contractual arrangements	2
Complicated and time-consuming modelling process	3
Doubts about Return on Investment	4
High Cost of implementation	5
Unclear benefits	6
the complicated and time-consuming modelling process	7

4.2.3.4 Technical Barriers

Many interviewees report the technical barriers for BIM implementation as shown in Table (37).

Table 37: Coding of Technical Barriers

Barriers	Ranking
Lack of BIM technical experts	1
Absence of standards and clear guidelines	2
Insufficient technology infrastructure	3
Interoperability	4
Current technology is enough	5

4.2.3.5 Organization Barriers

In table (38), many interviewees concluded organization barriers for BIM implementation.

Table 38: Coding of Organization Barriers

Barriers	Ranking
Lack of Senior Management support	1
Unwillingness to change	2
Difficulties in managing the impacts of BIM	3
Magnitude of Change / Staff turnover	4
Absence of Other Competing Initiatives	5
Construction Insurance	6

4.2.3.6 Market Barriers

Interviewees mention in table (39) market barriers for BIM implementation.

Table 39: Coding of Market Barriers

Barriers	Ranking
Lack of publicity and awareness	1
Lack of client/government demand	2

4.2.4 Removing barriers

The interviewees claimed that strategic change plans can remove most of the barriers. Government plays an important role to overcome the barriers. The government can conduct gaudiness, standards, and contracts, motivate organizations and participant in initial funding. The government can mandate BIM in its projects, collaborate with the universities and BIM software providers to train the organizations' employees and educate the university students to provide BIM experts. The interviewees suggested mixed approaches to expedite BIM implementation (top-down and down- top)

4.2.5 Key Factors influence BIM implementation

Interviewees suggested many factors representing a push for implementing BIM as follows:

1- Focusing on the knowledge part of BIM rather than the 3D model as globally, it is accepted that BIM is all about information, not just the vision.

2- BIM is about converting the design into reality, not to make just models for presentations. Tools used in BIM modules programs such as Revit, Auto-cad, sustainable arch 1&2 and others programs should be used for easier and more powerful information outputs.

3- The most important factors to implement the BIM are client and consultant, BIM system must be applied in the design stage, and the contractor cannot start working on BIM from scratch because of the long time required for modeling.

4- Announcement among specialized/related committees is highly demanded.

5- The decision should come from top management to spread the knowledge and train users.
6- Focus on BIM success stories to guide the market.
7- The government will need to support the BIM Process if they want to help the market.
8- The government should mandate BIM in KSA.
9- The government must have relation with the company produce programs in BIM as Vico office, Autodesk.
10- There is a need for BIM training for the engineers (another discipline) to excel in there filed.
11- Convince people in authority to enforce using BIM among companies and contractors.
12- All the internal stakeholders should collaborate through BIM especially in the area of coordination.
13- It's an area that the ROI and monitoring tools for the implementation must feed the results of performance to management with substantive facts and recommendations at strategic, process and people levels, especially in the Middle East and Saudi in particular
14- BIM needs more research for further development, it's not a solid science, and it needs to be integrated more with good training to achieve certainly the level that enables contractors/construction firms to solely depend on it.

4.2.5.1 External Push

Interviewees mentioned the factors for the external push to implement BIM which ranked in the table (40).

Table 40: Coding of External Push

External Push	Ranking
Providing guidance on use of BIM	1
Government support and pressure in the implementation of BIM	2
Provide education at university level	3
Developing BIM data exchange standards, rules and regulations	4
Perceived benefits from BIM to client	5
Collaboration with universities (Research collaboration and curriculum design for students)	6
BIM required by other project parties	7
Client pressure and demand the application of BIM in their projects	8
Clients provide pilot project for BIM	9
contractual arrangements	10
Promotion and awareness of BIM	11
Competitive pressure	12

4.2.5.2 *Internal Push*

As shown in table (41), interviewees respectively ranked the factors for the internal push to implement BIM.

Table 41: Coding of Internal Push

Internal push	Ranking
Top management support	1
Cultural change	2
Perceived benefits of BIM	3
BIM training program to staff	4
Improving built output quality	5
Continuous investment in BIM	6
The desire for innovation with competitive advantages and differentiation in the market.	7
Technical competence of staff	8
Financial resources of organization	9
Requirement for staff to be BIM competent	10
Improving the capacity to provide whole-life value to client	11
Safety into the construction process (reduce risk of accident)	12

4.2.6 AEC industry readiness and organizations capability

The interviewees ranked AEC industry readiness and organizations capability as shown in table (42).

Table 42: Coding of AEC industry readiness and organizations capability

Organizations capabilities	Ranking
Organizational decision due to the recognized benefits of BIM	1
Top managements' attitudes towards the implementation of BIM	2
Organization level of flexibility towards the change	3
Initial funding issues	4

In spite of many approaches such as frameworks (Succar, 2009; Kekana, et al., 2014; Succar & Kassem, 2015) and technology adoption (Masood, et al., 2014; Arayici, et al., 2011) have been proposed to support the implementation of BIM, the practical mechanism to adopt and implement BIM still lacks. Perhaps, this can be justified by looking at the status of BIM in both the developed (where BIM is mandated or nearly mandated) countries and developing (where BIM is still at its early stages) countries, which show the need for more practical and applied view of BIM rather than its potential benefits. Therefore, this research is trying to explore a practical methodology to implement BIM in KSA.

Chapter 5: Proposed model for BIM implementation

The research model, in Figure (56), developed from the extensive literature survey, the model proposed by (Omar, 2015) (Figure 55), and the recognized six factors influencing the implementation of BIM in the KSA AEC industry as the result of the questionnaire and the interviews analysis from the first stage of the data collection.

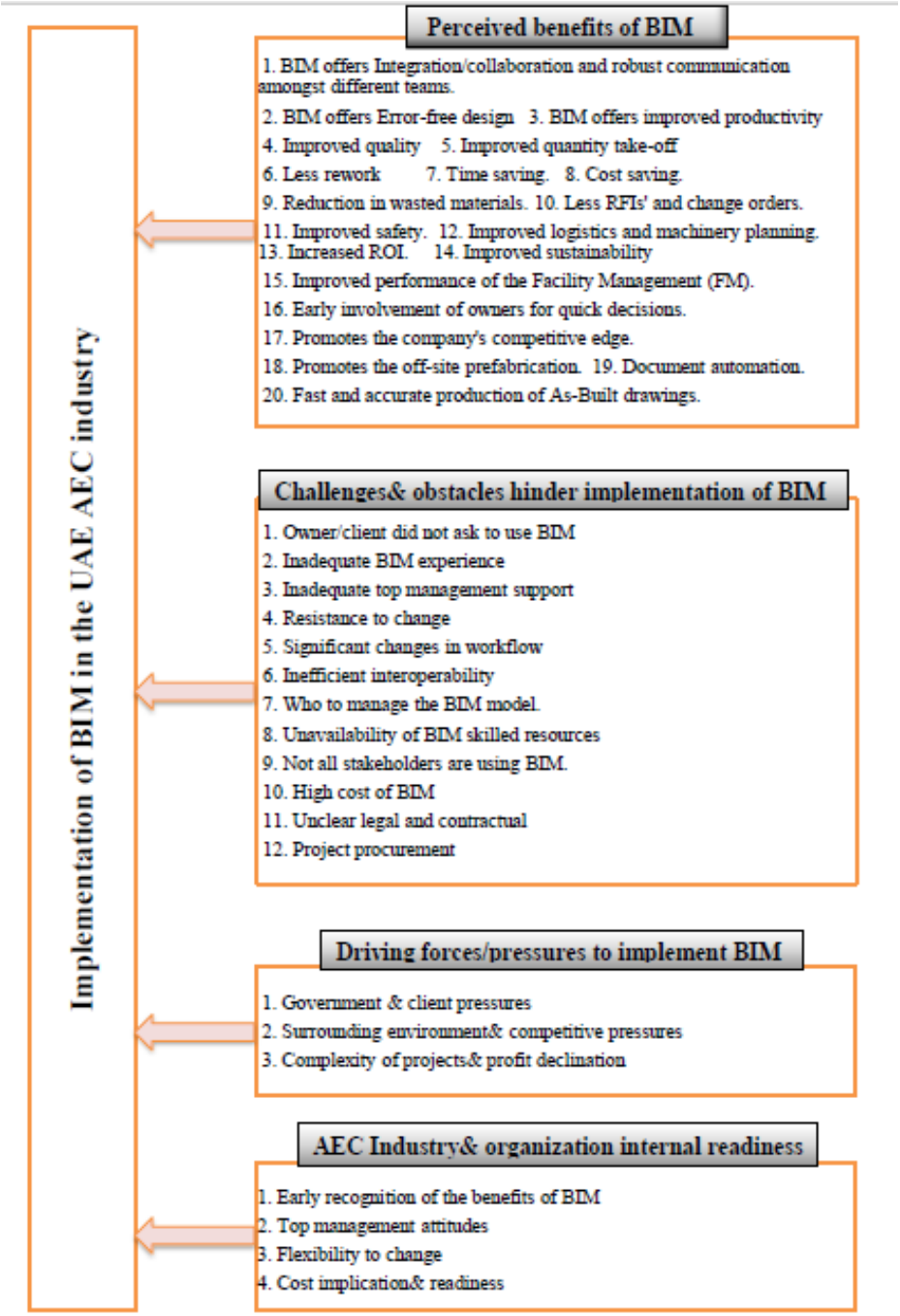
Implementation of BIM in the UAE AEC industry
Perceived benefits of BIM
1. BIM offers Integration/collaboration and robust communication amongst different teams.
2. BIM offers Error-free design 3. BIM offers improved productivity
4. Improved quality 5. Improved quantity take-off
6. Less rework 7. Time saving. 8. Cost saving.
9. Reduction in wasted materials. 10. Less RFIs' and change orders.
11. Improved safety. 12. Improved logistics and machinery planning.
13. Increased ROI. 14. Improved sustainability
15. Improved performance of the Facility Management (FM).
16. Early involvement of owners for quick decisions.
17. Promotes the company's competitive edge.
18. Promotes the off-site prefabrication. 19. Document automation.
20. Fast and accurate production of As-Built drawings.
Challenges& obstacles hinder implementation of BIM
1. Owner/client did not ask to use BIM
2. Inadequate BIM experience
3. Inadequate top management support
4. Resistance to change
5. Significant changes in workflow
6. Inefficient interoperability
7. Who to manage the BIM model.
8. Unavailability of BIM skilled resources
9. Not all stakeholders are using BIM.
10. High cost of BIM
11. Unclear legal and contractual
12. Project procurement
Driving forces/pressures to implement BIM
1. Government & client pressures
2. Surrounding environment& competitive pressures
3. Complexity of projects& profit declination
AEC Industry& organization internal readiness
1. Early recognition of the benefits of BIM
2. Top management attitudes
3. Flexibility to change
4. Cost implication& readiness

Figure 55: Implementation of BIM in the UAE AEC industry Model (Omar, 2015)

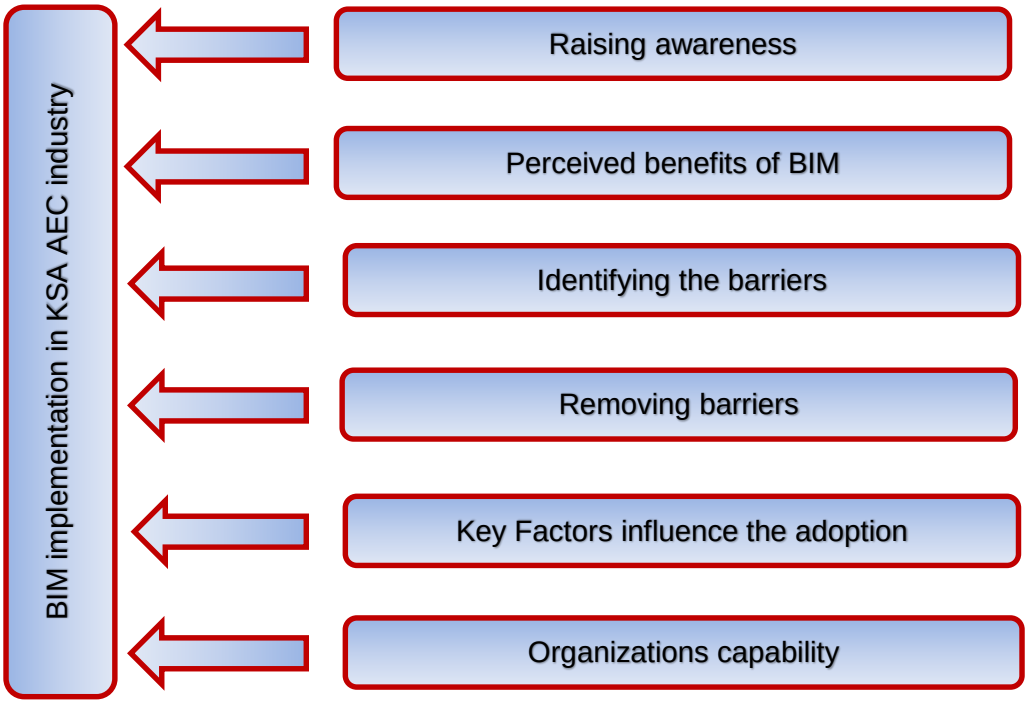

Figure 56: Conceptual Model for implementing BIM in KSA

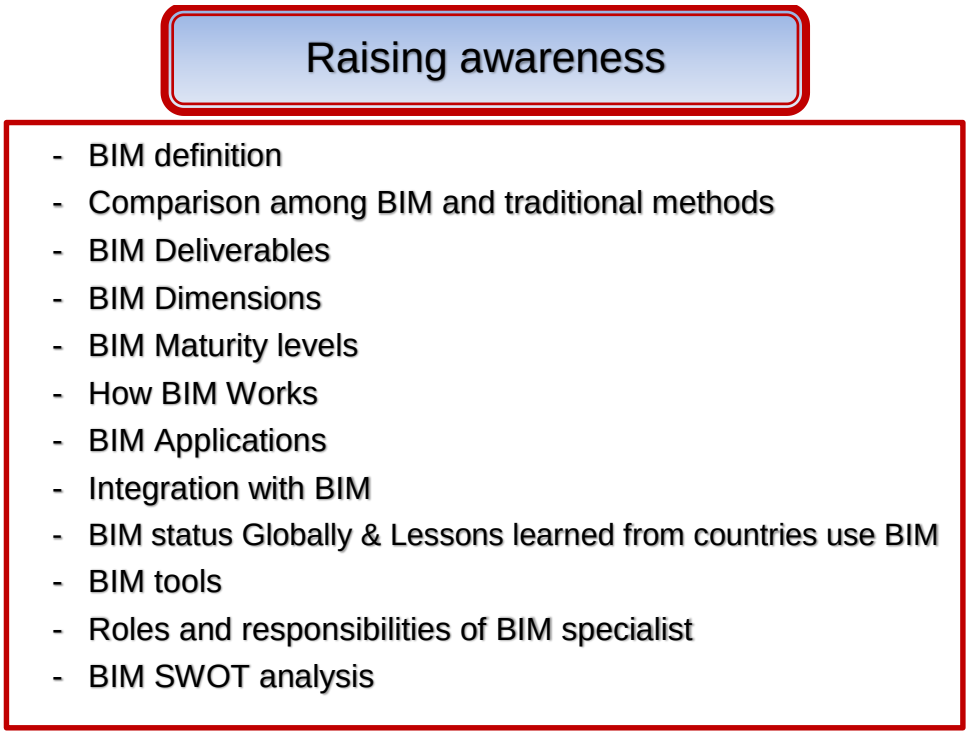
Raising awareness
- BIM definition
- Comparison among BIM and traditional methods
- BIM Deliverables
- BIM Dimensions
- BIM Maturity levels
- How BIM Works
- BIM Applications
- Integration with BIM
- BIM status Globally & Lessons learned from countries use BIM
- BIM tools
- Roles and responsibilities of BIM specialist
- BIM SWOT analysis

Figure 57: Raising awareness conceptual model

Perceived benefits of BIM

Client perspective
Information Model
Reducing financial risk
Evaluating project performance & maintenance
Ensuring Project Requirements
Enabling several marketing techniques
Designer perspective
Facilitating visual evacuation plans
Enabling Sustainable analysis
Producing Various design options (Creativity & innovative solutions) and Error-free design
Extracting fast IFC drawings
Contractor perspective
Enable 3D Coordination
Information Integration
Accurate BOQ & Cost Estimation
Supporting construction ,performance , project management and facility management
Monitor & Control Progress
Site Utilizing Planning
Enhanced ability to compete (Promotes the company's competitive advantage)
Automated assembly
Increase Health & Safety
Staff recruitment and retention
Promotes the off-site prefabrication (JIT)
Fast and accurate production of As-Built drawings
Positive ROI
Increasing productivity
Increased profitability
Maintain repeat Business
Shared benefits (to all participants)
Clash detection
Time savings
Improving the quality and Reduced Rework
Increasing efficiency
Enhance collaboration , Coordination & communication
The cost reduction
Creation and sharing of information ability: Lifecycle data
Reduced Document Errors and omissions
Improves visualization
Reduced Number of requests for information

Reduced change orders
Reduce Waste and value generation
Reduced claim and law issues
Early client involvement (quick decisions & Meet client satisfaction)
Improve decision making
Integration with other Knowledge or concept (GIS, lean construction, green building)
Maintain control
Enhance creativity and innovations
Reliable sustainability analysis
Overcome the geographical distance barriers
Help procurement
Preserve the materials and the environment
Meet client satisfaction

Figure 58: Perceived benefits of BIM conceptual model

Identified the Barriers

Personal Barriers
Lack of understanding of BIM and its benefits
Resistance to change: Lack of skills development
Lack of BIM education
Lack of insufficient training
Lack of BIM knowledge in applying current technologies
Process Barriers
Changing work processes
Lack of effective collaboration among project participants
Risks and challenges with the use of a single model (BIM)
Legal issues (ownership of data- traditional procurement)
Other stakeholders are not using BIM
Business Barriers
Time and Cost of training
Lack of contractual arrangements
Complicated and time-consuming modelling process
Doubts about Return on Investment
High Cost of implementation
Unclear benefits
Technical Barriers
Lack of BIM technical experts
Absence of standards and clear guidelines
Insufficient technology infrastructure
Inefficient Interoperability
Current technology is enough
Updating of the information
Organization Barriers

Lack of Senior Management support
Unwillingness to change
Difficulties in managing the impacts of BIM
Magnitude of Change / Staff turnover (roles and responsibilities issues)
Absence of Other Competing Initiatives
Financial issue
Construction Insurance
Lack of BIM experience (Know-how)
Market Barriers
Lack of publicity and awareness
Lack of client/government demand
Remove the identified barriers
Developing strategic plans to remove each barrier

Figure 59: Identified the Barriers conceptual model

Main Factors Influencing the Adoption of BIM

External Push
Providing guidance on use of BIM
Government support and pressure in the implementation of BIM
Provide education at university level
Developing BIM data exchange standards, rules and regulations
Perceived benefits from BIM to client
Collaboration with universities (Research collaboration and curriculum design for students)
BIM required by other project parties
Client pressure and demand the application of BIM in their projects
Clients provide pilot project for BIM
contractual arrangements
Promotion and awareness of BIM
Competitive pressure
Availability of appropriate software and hardware
Internal Push
Top management support
Cultural change
Perceived benefits of BIM
BIM training program to staff
Improving built output quality
Continuous investment in BIM
The desire for innovation with competitive advantages and differentiation in the market.
Technical competence of staff
Financial resources of organization
Requirement for staff to be BIM competent
Improving the capacity to provide whole-life value to client
Safety into the construction process (reduce risk of accident)
Collaboration among all project parties
Projects complexity and profit declination

Figure 60: Main Factors Influencing the Adoption of BIM conceptual model

Organizations capabilities	Ranking
Organizational decision due to the recognized benefits of BIM	1
Top managements' attitudes (support) towards the implementation of BIM	2
Organization level of flexibility towards the change	3
Initial funding issues	4

Figure 61: Organizations capability conceptual model

This study discusses the six recognized factors (enumerated in Figures 57 to 61) identified from the literature and the results of the second stage of this research. The level of maturity readiness will be investigated to implement and mandate effectively BIM considering the six factors. The proposed conceptual model is expected to assist the KSA AEC industry players to recognize the gaps that diminish the chances for the successful implementation of BIM. The following sections discuss the research hypothesis.

5.1 Developing the hypothesizes

5.1.1 Raising awareness (independent variable):

This factor aims to increase the KSA AEC industry players' knowledge about BIM including BIM definition, BIM deliverables, BIM dimensions, maturity level, the comparison between BIM and CAD, BIM applications, integration with BIM, BIM status globally, lessons learned from countries using BIM, and how BIM works. Raising awareness highly influences the decision for the implementation of BIM.

The study checks the validity of a first hypothesis, *H1: The higher the appropriate raising awareness, the greater opportunities for the successful implementation of BIM.* That means the more recognition and appropriate awareness of BIM, the more assistance and encouragement to the organizations and the KSA AEC industry decision makers to implement BIM.

5.1.2 The perceived benefits of BIM (independent variable):

This factor refers to the anticipated benefits and advantages that the use of BIM can offer to the organization and entire AEC industry. The perceived benefits of BIM are highly influencing the decision for the implementation of BIM.

The study checks the validity of a second hypothesis, *H2: The higher the appropriate recognition of the benefits of BIM, the greater opportunities for the successful implementation of BIM.*

5.1.3 Barriers to implementing BIM (independent variable):

This factor refers to the obstacles that diminish the chances of the implementation of BIM.

The study checks the correctness of the third hypothesis *H3: The higher the level of barriers, the lesser opportunities for the implementation of BIM.* That means the pre-recognition of the barriers will greatly assist the organizations and the industry to deal with these impediments and promote the chances of the implementation of BIM.

5.1.4 Remove the barriers to implementing BIM (independent variable):

This refers to remove the obstacles that diminish the chances of the implementation of BIM.

The study checks the correctness of the fourth hypothesis *H4: The more the barriers to be removed, the higher the opportunities for successful BIM implementation.* That means the capability of removing the barriers will greatly assist the organizations and the industry to deal with these obstacles and promote the opportunities for the implementation of BIM.

5.1.5 Key factors influence the BIM adoption (independent variable):

This includes two main categories:

- The main driving forces: or the external factors which are recognized as the external pressure from authorities either the government or the client to impose the utilization and mandate of BIM as a compulsory requirement.
- Assistance factor: or the internal factors, including individual, organizations, software suppliers.

The study checks the correctness of the fifth hypothesis *H5: The more the adoption of factors influencing BIM, the greater opportunities for the implementation of BIM*. These factors are deemed to have a positive impact on BIM implementation.

5.1.6 The KSA AEC industry readiness and organisations capability (independent variable):

This refers to the organization and industry level of preparation and readiness to adopt the change initiatives.

The study checks the correctness of the sixth hypothesis *H6: The higher the internal readiness to adopt the change to BIM, the greater the opportunities for successful implementation of BIM.* That means the internal readiness of the

organization and the KSA AEC industry is crucial to driving the success towards the implementation of BIM.

5.1.7 Implementation of BIM in the KSA AEC industry (The dependent variable):

This refers to the readiness and the maturity level of the KSA AEC industry to implement and mandate BIM. This level of maturity varies from not at all adopting BIM and even not willing to adopt BIM to being fully committed and supportive to implement BIM. This dependent variable is directly influenced by the four independent variables as suggested in the conceptual framework model and the proposed hypotheses. Therefore, considering the aforementioned variables are imperative to the study the successful transition to the implementation of BIM on the organizations and the KSA AEC industry levels.

5.2 Model validation

5.2.1 Questionnaire

For rapid validation of the conceptual model, an online questionnaire has been sent to highly professional BIM experts who are working in KSA from different nationalities. The questionnaire was sent to 150, received responses was (48).

5.2.1.1 Respondents data

5.2.1.1.1 Organization Sector

Figure (62) demonstrates that most of the questionnaire respondents represent the private sector.

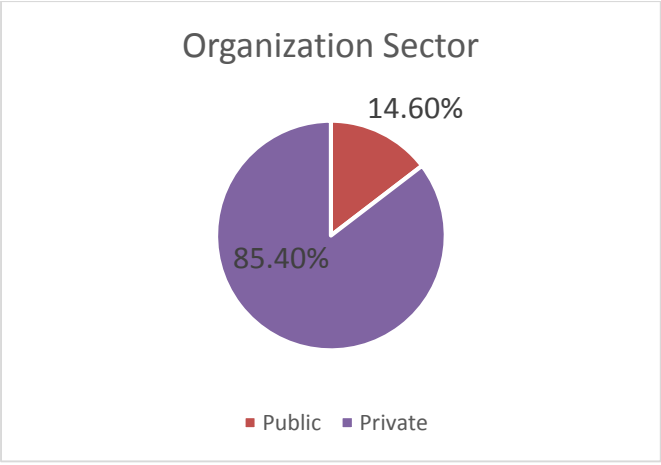

Figure 62: Organization Sector

5.2.1.1.2 Number of organization employees

The number respondents' organization employees are over 200. This means that BIM awareness is of the highest level in large organizations as shown in Figure (63).

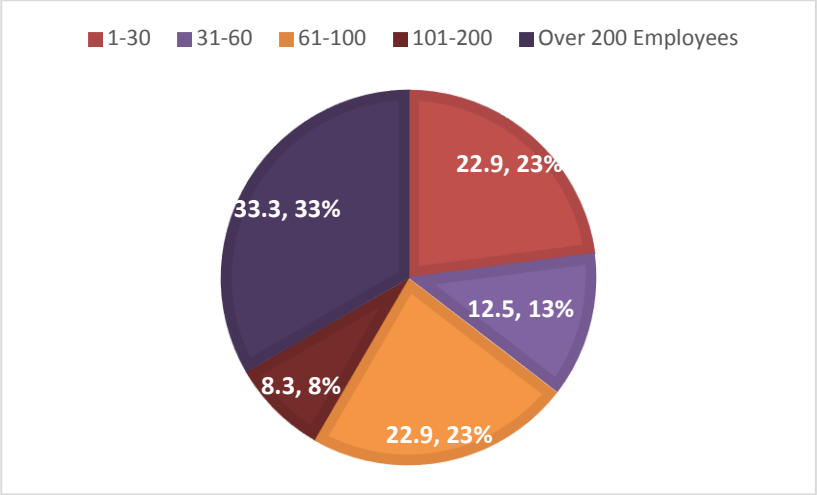

Figure 63: organization size

5.2.1.1.3 Project budget in SAR

As shown in Table 43 and Figure 64, projects' budgets of most respondents are less than fifty million SAR.

Table 43: Project budget

Project budget in SAR	Frequency	Percent
Less than 50 M (Million)	19	39.6
51-100 M	9	18.8
101-200 M	5	10.4
201-500 M	7	14.6
501 M-1B (Billion)	3	6.3
More than 1B	5	10.4
Total	48	100.0

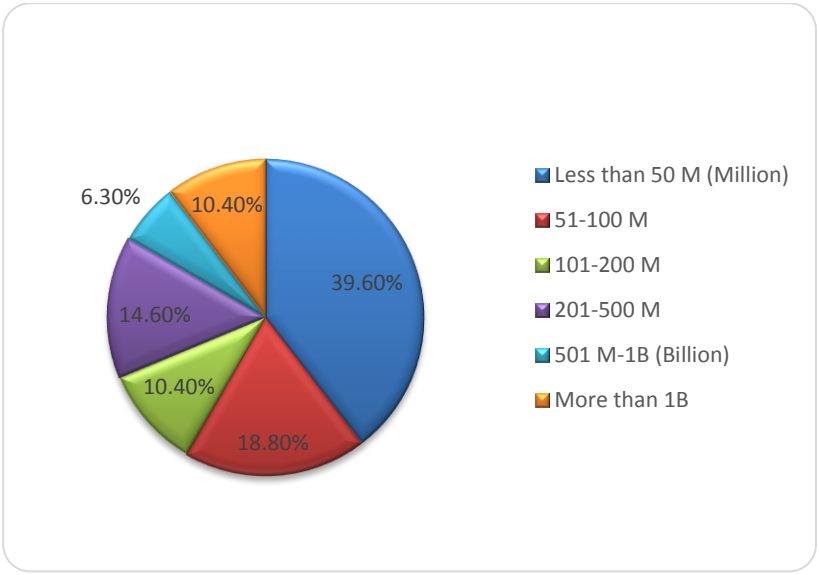

Figure 64: Project budget

5.2.1.1.4 Position in Company

Table (44) and Figure (65), revealed that the position of the most respondents is an architect. So, designers are the most interested in BIM.

Table 44: respondents Position in their Company

Position in Company	Frequency	Percent
Director/ Vice	7	14.6
Upper manager	3	6.3
Project/section manager	9	18.8
Technical Office Engineer	3	6.3
Architect	10	20.8
BIM manager	9	18.8
BIM Designer	4	8.3
Researcher / Academic	3	6.3
Total	48	100.0

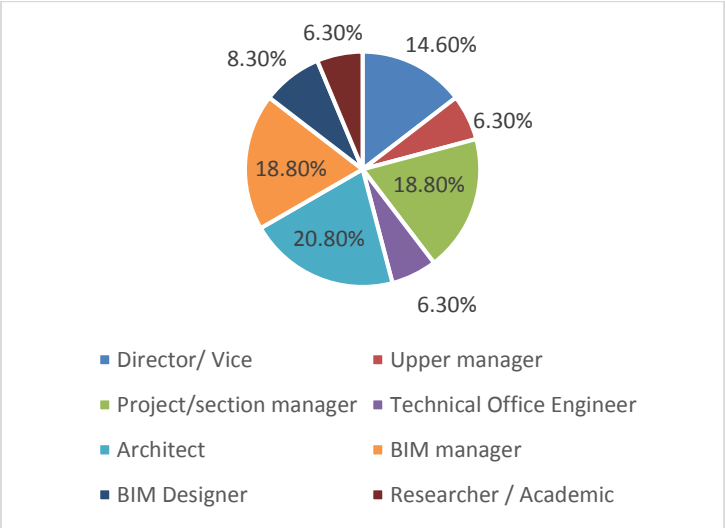

Figure 65: respondents Position in their Company

5.2.1.1.5 Education Level

Most respondents' education level is BSc followed by MSc that mean the most interested and influence the BIM implementation are the BSc and MSc holders as shown in Table (45).

Table 45: respondents' Education Level

Education Level	Frequency	Percent
BSc	24	50.0
MSc	23	47.9
PhD	1	2.1

5.2.1.1.6 Years of experience

Most of the respondents are 5-10 years of experience that means fresh graduates are not aware of BIM due to lack education and the old graduates don't keep up with the latest technology Table (46).

Table 46: respondents' years of experience

Years of experience	Frequency	Percent
Less than 5 yrs.	4	8.3
5-10 yrs.	19	39.6
11-15 yrs.	10	20.8
16-20 yrs.	9	18.8
More than 20 years	6	12.5

5.2.1.2 Reliability and questionnaire data tests

5.2.1.2.1 Reliability

Table 47: Models Validation Reliability

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.954	.955	6

As discussed in section 4.1.1.1, the reliability equals to 0.955 (Table 47) more than 0.70, it means that the Questionnaire data is highly reliable.

5.2.1.2.2 Correlation

As illustrated in section 4.1.1.2, the correlation between the variable (Table 48) is very strong and the result would be considered statistically significant.

Table 48: Correlations

		Raising awareness	Perceived benefits of BIM	Identifying barriers (first step for plan to remove it)	Removing the barriers	Key Factors influence the adoption	Organizations capability
Raising awareness	Pearson Correlation	1	.707**	.690**	.770**	.766**	.778**
	Sig. (2-tailed)		.000	.000	.000	.000	.000
	N	48	48	48	48	48	48
Perceived benefits of BIM	Pearson Correlation	.707**	1	.793**	.795**	.799**	.722**
	Sig. (2-tailed)	.000		.000	.000	.000	.000
	N	48	48	48	48	48	48
Identifying barriers (first step for plan to remove it)	Pearson Correlation	.690**	.793**	1	.847**	.814**	.754**
	Sig. (2-tailed)	.000	.000		.000	.000	.000
	N	48	48	48	48	48	48
Removing the barriers	Pearson Correlation	.770**	.795**	.847**	1	.843**	.873**
	Sig. (2-tailed)	.000	.000	.000		.000	.000
	N	48	48	48	48	48	48
Key Factors influence the adoption	Pearson Correlation	.766**	.799**	.814**	.843**	1	.751**
	Sig. (2-tailed)	.000	.000	.000	.000		.000
	N	48	48	48	48	48	48
Organizations capability	Pearson Correlation	.778**	.722**	.754**	.873**	.751**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	48	48	48	48	48	48

**. Correlation is significant at the 0.01 level (2-tailed).

5.2.1.3 Results

The respondents ordered the six independent variables which impact the dependent variable (implementing BIM in KSA AEC industry) as (1) Perceived benefits of BIM, (2) AEC industry redness and organizations capability, (3) Raising awareness, (4) Identifying barriers, (5) Removing the barriers, (6) Key Factors influence the implementation (Figure 66 and Table 49).

The weighted mean of the respondents about raising awareness is 4.02, so the first hypothesis, (H1: *the higher the appropriate raising awareness the greater opportunities for the successful implementation of BIM*) is accepted.

The weighted mean of the respondents about perceived benefits of BIM is 4.18, so the second hypothesis (H2: *the higher the appropriate recognition of the benefits of BIM, the greater opportunities of the successful implementation of BIM*) is accepted.

The weighted mean of the respondents about identifying barriers is 4.02, so the third hypothesis (H3: *the higher the barriers, the lesser opportunities for the implementation of BIM)* is accepted.

The weighted mean of the respondents about removing the barriers is 4.0, so the fourth hypothesis (H4: *The more the barriers to be removed, the higher the opportunities for successful BIM implementation*.) is accepted.

The weighted mean of the respondents about key factors influence the adoption is 3.93 so the fifth hypothesis (H5: *The more the adoption of factors influencing BIM, the greater opportunities of the implementation of BIM*.) is accepted.

The weighted mean of the respondents about Organisations capability is 4.06, so the sixth hypothesis (H6: *The higher the internal readiness to adopt the change to BIM, the greater the opportunities for successful implementation of BIM*.) is accepted. From all research steps, the suggested methodology for BIM implementation in KSA was generated as in Figure (67).

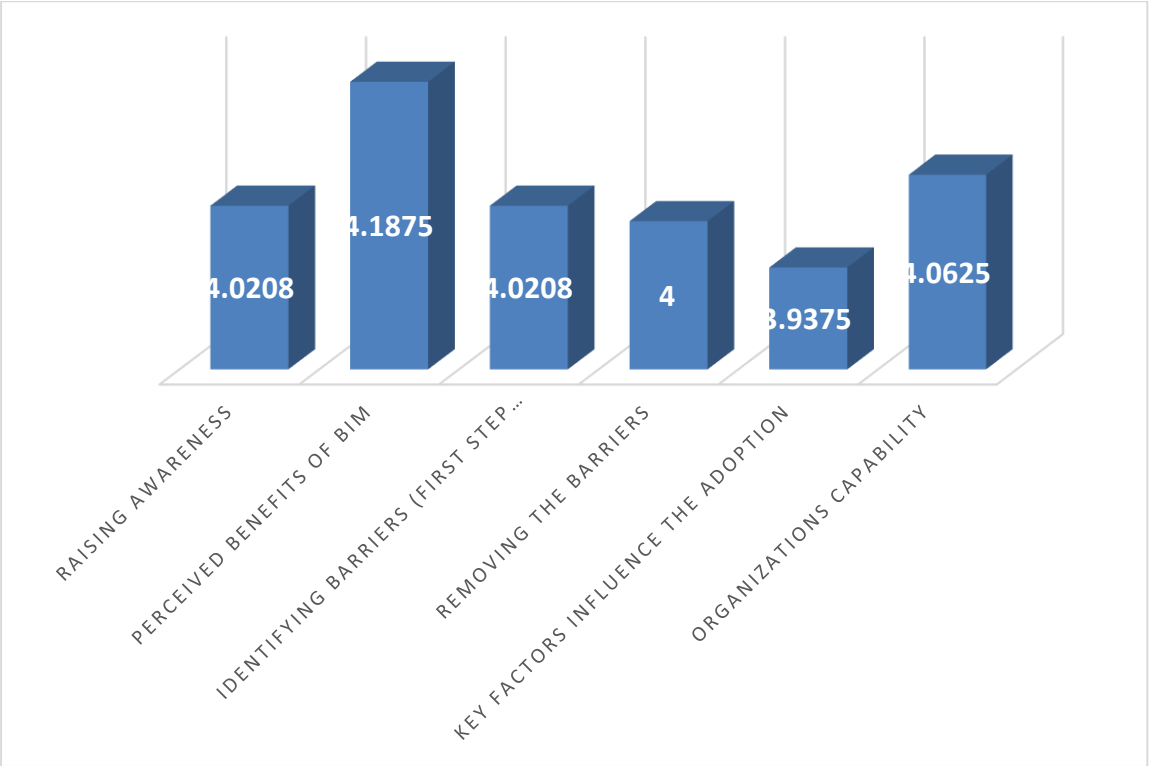

Figure 66: independent variables impact the BIM implementation in KSA

Table 49: independent variables impact the BIM implementation in KSA

Independent variable	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total	Weighted mean	Std. Deviation	Ranking	The general trend
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency				
	Percent	Percent	Percent	Percent	Percent	Percent				
Raising awareness	5	1	8	8	26	48	4.0208	1.32873	3	Agree
	10.4 %	2.1 %	16.7 %	16.7 %	54.2 %	100 %				
Perceived benefits of BIM	3	2	6	9	28	48	4.1875	1.19674	1	Agree
	6.3 %	4.2 %	12.5 %	18.8 %	58.3 %	100 %				
Identifying barriers	3	3	8	10	24	48	4.0208	1.22890	3	Agree
	6.3 %	6.3 %	16.7 %	20.8 %	50 %	100 %				
Removing the barriers	2	4	9	10	23	48	4.0000	1.18501	4	Agree
	4.2 %	8.3 %	18.8 %	2.8 %	47.9 %	100 %				
Key Factors influence the adoption	3	2	11	11	21	48	3.9375	1.19228	5	Agree
	6.3 %	4.2 %	22.9 %	22.9 %	43.8 %	100 %				
Organisations capability	3	2	8	11	24	48	4.0625	1.19228	2	Agree
	6.3 %	4.2 %	16.7 %	22.9 %	50 %	100 %				
Weighted mean							4.038			Agree

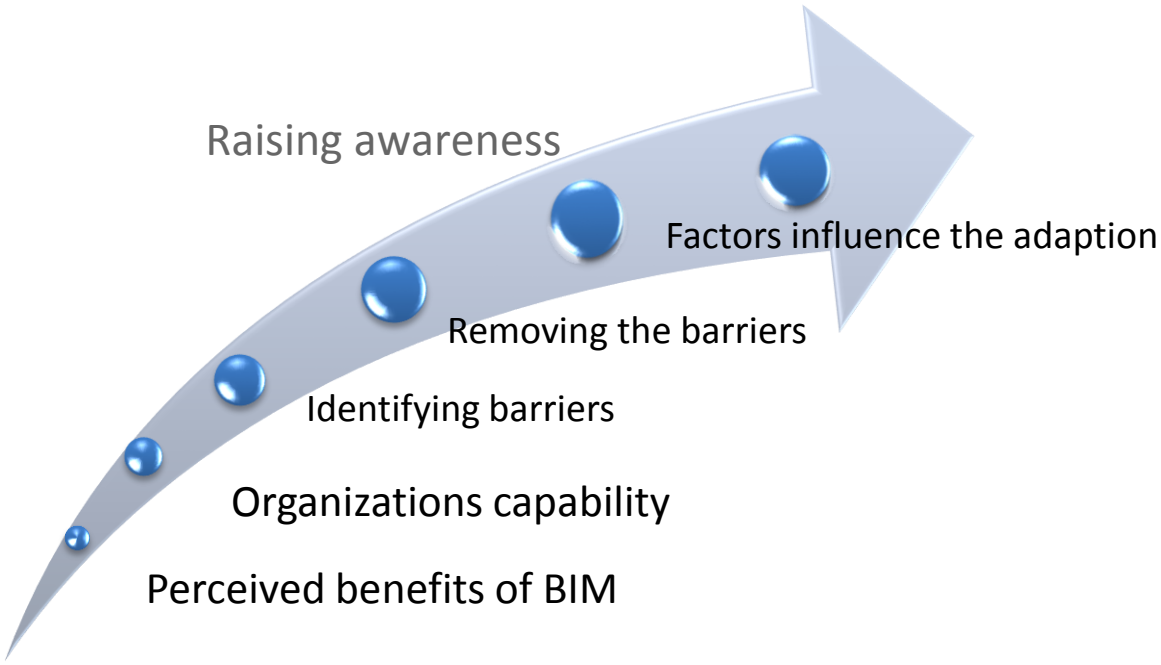

Figure 67: Suggested Methodology for implementing BIM in KSA

5.2.2 Interviews

5.2.2.1 Validating the suggested models

Structured 50 interviews organized to validate the conceptual models (Figure 57:61) and the suggested Methodology in Figure (67) which developed from extensive literature, results from the second stage of this research and results from the to-be-validated model questionnaire stage.

The interviewees review all the contents of the conceptual models, they did not add any point and agree with the whole model. Therefore, we can claim that the models in (Figure 57:61) are final models.

The interviewees ordered the independent variables which impact the BIM implementation in KSA, as shown in Table (50).

Table 50: Coding of variables impact BIM implementation

Independent variable	Ranking
Raising awareness	1
Perceived benefits of BIM	2
Organisations capability	3
Identifying barriers	4
Removing the barriers	5
Key Factors influence the adoption	6

5.2.2.2 Validating the suggested methodology

Most of the interviewees agree with the steps of the suggested methodology, and they confirm those are enough, but slight conflicts about the order of the steps.

For example, Karen Fugle (Executive Coaching for Architects & Designers) reported that “factors influencing the implementation is possibly the road that you travel on - not a point on it. Factors will be there from the very beginning - attitudes/beliefs/money/resources/leadership etc. - and will change as the journey continues. Perhaps not a path, but a cyclical process.”

Hector Camps, (Building Smart Alliance and New Jersey Institute of Technology) said that “Define desired BIM outcomes, and think what you want to achieve once it's all implemented.”

Per David Sannes, (Digital Construction Management, BIM & IPD for AECO & MEP, Media, Information Design: Curriculum, Programs & Courses), said that” The perceived benefits of BIM, in my mind, should be the actual benefits of BIM. The perception happens in the mind of the person who has never used BIM in the construction process before. This is a transition from 2D thinking in the construction process to 3D+, visualization and simulation of a true digital construction asset to be used in conjunction with the projects life cycle plan. It's like telling someone who has been doing something their whole life that their industry has become a tech industry and its benefits are the base that the next generations of construction will have a foundation on. Custom manufacturing using 3D printing and milling, component and modular construction, you can't use these if you do not use BIM.”

Additionally, Ayman Kandeel reported that “to implement BIM in KSA, the first step should be raising awareness, secondly, conceive the key decision makers about perceived benefits of BIM, then make a feasibility study to prove the profit and BIM benefits acquired from implementing BIM. The last step is to develop strategic plan with consideration of Experiences and examples of successful application of BIM from countries using BIM.”

Eng. Hossam Mohammed commented on the methodology “There is a very important role of the government and this must be a part not separated from the plan, while the government considered this system all clients and establishment will follow it”

However, Bilal Succar, (Ph.D. and BIM key author), agreed with the methodology, he suggested that it can be applied for organisations and need more modification if it is applied to the overall KSA AEC industry projects.

Juan José Guzman Carvajal, Engineering Training & Development Consultant, said that “To implement BIM in any organization, The first step is to create a community of practices.”

Additionally, the methodology discussed on Linked in the group titled with “BIM Experts” which includes 61,989 members. The post which required BIM experts’ perspective about the suggested methodology gained 56 likes and 35 comments all of them agreed and confirmed the steps to implement BIM in KSA AEC industry projects.

Also, to test the hypotheses, the interviewees and all comments from the group members reported that BIM implementation impacted by the six factors (raising awareness, perceived benefits of BIM, organizations capability, identifying barriers, removing the barriers, Key factors influence the adoption), so the 6 hypotheses could be accepted.

Chapter 6: Conclusions

The focus of the construction industry now is to eliminate waste and inefficiency to improve quality and profitability. However, BIM proved its competence on this way to eliminate waste and insufficiency motivated developed counties to use and mandate BIM. There are only limited examples of BIM implementation within the AEC Industry and AEC education in KSA.

Due to not only solving the massive problems with AEC industry projects and reaping the benefits from implementing BIM, but also to improve the projects performance and efficiency which in turn Motivates This research to find ways For BIM implementation in KSA to pave the way to facilitate using BIM and to increase the chances to find a creative and an innovative alternative solutions to the AEC industry project issues and raising the quality and profitability. This research could represent a guide to all AEC industry projects stockholders to raise the awareness about BIM, benefits gained from using BIM, barriers hinder BIM implementation, key factors influencing the implementation. And answering any question may be raising related to BIM such as what is BIM mean? How can we use BIM? , why do we use BIM? , who can use BIM? And so on.

This research illustrates the knowledge gap by extensive research and how the research covered them by using the suitable suggested research methodology to achieve the stipulated aim and objectives and answering the research questions.

The key findings of this research are: (1) There is low level of BIM awareness about BIM in KSA AEC industry, (2) Suggested ways to raise the awareness, (3) Identifying the Benefits from all project parties' perspectives, (4) Determined of the main barriers hinder the BIM implementation,(5) Proposed stratigies to remove the barriers,(6) Exploring the main driving forces and the main external pressures pushing the implementation of BIM in the KSA AEC industry, (7) Identifying the main internal pushs, the AEC industry readiness, and the organizations capabilities to implement BIM.

The following subsections conclude the findings of this research.

6.1 Raising BIM awareness

6.1.1 BIM definition

It can be argued that the different focuses of both researchers generated two different definitions, also, this research figures out that every professional has his own BIM definition, but the concept of BIM is unchanged.

However, researchers and professionals don't have unified definition for BIM, they have an agreement that the concept of BIM is the same and advise the AEC

industry decision makers and companies to collaborate on mandating BIM to reap its benefits. BIM is considered as an environment that combines all requirements and efforts from all project participants through various project phases to produce an efficient creative and innovative product replying all parties and project objectives.

6.1.2 Comparison among BIM and traditional methods

The interviewees claimed the same comparisons which have been already explained in section 2.2.2 in the literature review.

6.1.3 BIM deliverables

According to the interviewees, BIM deliverables could be (1) Providing contractor's Information Requirements (2) Clash prevention (3) 3D model validation (4) 3D model take-off (5) 3D model-based meetings (6) Compliance with Employers Information Requirements (EIR) (7) Common Data Environment (CDE) (8) Digital Plan of Work (describing Level of Detail – LoD / CIC Work Stages) (9) Intelligent 3D libraries (10) 3D-based collaboration (11) 3D digital survey (12) Asset performance optimization and Construction Operations Building Information Exchange(COBie).These results correspond to what the literature provided.

6.1.4 BIM dimensions

The interviewees and the questionnaire respondents concluded that there is 7 Ds as BIM Dimensions which are 3D, 4D, 5D, 6D, and 7D. However, developed countries are trying to integrate these dimensions to enhance the gained benefits from BIM, while developing countries including KSA are still in the first stage using 3D dimensions.

6.1.5 BIM maturity levels

Interviewees and questionnaire respondents argued that there are four levels of BIM maturity. However, developed countries such as the UK are swiftly trying to upgrade from level 2 to level 3, Developing countries (including KSA) are still in level 0 trying to adopt level 1.

6.1.6 How BIM works

The interviewees claimed the same procedures that illustrate at section 2.2.6 in the literature.

6.1.7 BIM applications

A wide acceptance is found between interviewees and questionnaire respondents that BIM could be used in interaction with non-professionals, design analysis, drawing production, project scheduling (programming), cost estimating, tendering, quantity Surveying. Besides, site layout planning, support constructability and

analysis, safety (training and education, design, planning, accident investigation, and facility and maintenance phase), collaboratively created, shared, and maintained models across the project lifecycle.

6.1.8 Integration with BIM

To either questionnaire respondents and interviewees, BIM could integrate with: (1) Lean construction, (2) Geography information system (GIS), (3) Enterprise Resource Planning (ERP), (4) Virtual Reality, Facility Maintenance, (5) Integrated Project Delivery (IPD), (6) Augmented reality for interactive architectural visualization, (7) Project management, (8) Computer-aided facility management (CAFM), (9) Health and, Green Building, (10) Construction management education, (11) Just in time production, (12) Total Quality Management and Six Sigma.

6.1.9 BIM status globally and lessons learned from countries using BIM

Lessons learned from earlier BIM users such as UK, USA, Australia and New Zealand must be taken in consideration to shorten the way and start up from the point that others have already achieved then continue and choose the most suitable for KSA environment.

6.1.10 BIM software

Every BIM expert uses the tools that respond his requirements and achieve his objectives. Both interviewees and questionnaire respondents use BIM as following:

Architectural model: Architectural Desktop, Bentley Architecture, V8, Vectorworks, Revit Architecture

Structural model: X Steel, SDS/2, QuickPen, CADPIPE, SOFTEK, Revit Structure, CSC, Tekla Structure, ETABS, RISA, SoFiSTiK, Bentley Structure, Orion

Mechanical, Electrical and Plumbing (MEP) model: Revit MEP, Bentley Mechanical, Hevacomp Mechanical designer, 3D pipe designer, AutoCAD MEP, CADPIPE electrical, HVAC System design, CADMECH, CAMduct, Multi-pipe, Bentley Electrical, Autopipe

Schedule and time model: MS Project, Primavera, Bentley Schedule Simulator, Jet-Stream timeliner, Ebuilder, Newforma.

Resources and cost model: MS Project, IES, Autodesk QTO, Cost X, Ideate BIM link, Sefaira, Planswift, Timberline, Vico Cost Planner, Innovaya Visual Estimating

Construction and site utilization: model Unity 3D game engine, AutoCAD Civil 3D, Power Civil, InRoads Site, Hevacomp Simulator, Bentley Simulator

Operation and maintenance model: CMMS, IBM Maximo, Bentley facilities, Autodesk FM desktop, One Tool, Geospatial and facilities

Sustainability model: IESVE, Autodesk Green Building Studio

This result is similar to (Computer Integrated Construction Research Program (CICRP), 2012; Olugboyega, 2017) results.

6.1.11 Roles and responsibilities of BIM specialist

The interviewees claimed the same roles and responsibilities that have been illustrated in section 2.2.11 in the literature.

6.1.12 BIM SWOT analysis

The interviewees claimed that every organisation has its BIM SWOT analysis which in turn facilitates the decision to implement BIM or not.

6.2 Perceived benefits of BIM

6.2.1 Client perspective

The questionnaire respondents and interviewees ordered the main benefits from a client perspective as (1) Information Model, (2) Reducing financial risk, (3) Evaluating project performance & maintenance, (4) Ensuring Project Requirements, (5) Enabling several marketing techniques. These benefits are similar to those in the literature, but this result provides their order.

6.2.2 Designer perspective

Unlike the literature, interviewees and questionnaire respondents in this result respectively ordered the main benefits of BIM from designer perspective as: (1) Facilitating visual evacuation plans, (2) Enabling sustainable analysis, (3) Producing various design options (Creativity & innovative solutions), (4) Error-free design, (5) Extracting fast IFC drawings.

6.2.3 Contractor perspective

To both interviewees and questionnaire respondents, the main benefits from contractor perspective are: (1) Enabling 3D coordination, (2) Information integration, (3) Accurate BOQ & cost estimation, (4) Supporting construction ,performance , project management and facility management, (5) Monitoring & controlling progress, (6) Site utilizing planning, (7) Enhanced ability to compete (Promotes the company's competitive advantage), (8) Automated assembly, (9) Increasing, (10) Health and safety, (11) Staff recruitment and retention, (12) Promoting the off-site prefabrication (JIT), (13) Fast and accurate production of As-Built drawings, (14) Positive ROI, (15) Increasing productivity, (16) Increasing profitability, and (17) Maintaining repeat business.

These results are on the same line with the literature but in a different order.

6.2.4 Shared benefits (to all participants)

The shared benefits of BIM to all participants according to interviewees and questionnaire respondents could be ordered respectively as: (1) Clash detection, (2) Time-saving, (3) Improving the quality and reduced rework, (4) Increasing efficiency, (5) Enhancing collaboration, coordination & communication, (6) cost reduction, (7) Creation and sharing information ability, (8) Providing life cycle data, (9) Reducing document Errors and omissions, (10) Improving visualization, (11) Reducing number of requests for information, (12) Reducing change orders, (13) Reducing waste and value generation, (14) Eliminating claim and law issues, (15) Early client involvement (quick decisions and meet client satisfaction), (16) Improvement of decision making, (17) Integration with other knowledge or concept (GIS, lean construction, green building), (18) Control maintenance, (19) Enhancing creativity and innovations, (20) Reliable sustainability analysis, (21) Overcoming the geographical distance barriers, (22) Helping procurement, (23) Preservation of materials and the environment, (24) Meeting client satisfaction. Although the results are the same as literature, the order is different.

6.3 the AEC industry readiness and organizations capabilities

The questionnaire respondents and interviewees classified the AEC industry readiness and organizations capabilities as organizational decision related to the recognized benefits of BIM, top managements' attitudes (support) towards the implementation of BIM, organizational level of flexibility towards the change, initial funding issues. This result agrees with the literature.

6.4 Identification of the barriers:

6.4.1 Personal barriers

Parallel to the literature, interviewees and questionnaire respondents identified the personal barriers as: (1) Lack of understanding of BIM and its benefits, (2) Resistance to change, (3) Lack of development skills, (4) Lack of sufficient training and BIM education, (5) Lack of BIM knowledge in applying current technologies, but this result orders them differently.

6.4.2 Process barriers

Unlike the literature, interviewees and questionnaire respondents respectively ordered process barriers as: (1) Changing work processes, (2) Lack of effective collaboration among project participants, (3) Risks and challenges with the use of a single model (BIM), (4) Legal issues (ownership of data- traditional procurement), (5) Other stakeholders are not using BIM.

6.4.3 Business barriers

However, interviewees and questionnaire respondents in this study agreed with the literature about business barriers concluded as: (1) Time and cost of training, (2) Lack of contractual arrangements, (3) Complicated and time-consuming modelling process, (4) Doubts about return on investment, (5) High cost of implementation, (6) Unclear benefits, both disagreed about their order.

6.4.4 Technical barriers

The questionnaire respondents and Interviewees respectively ordered the technical barriers as (1) Lack of BIM technical experts, (2) Absence of standards and clear guidelines, (3) Insufficient technology infrastructure, (4) Inefficient Interoperability, (5) Current technology is enough, (6) Updating of the information, but the literature differently ordered them.

6.4.5 Organization barriers

Interviewees and questionnaire respondents stated that organization barriers would be: (1) Lack of Senior management support, (2) Unwillingness to change, (3) Difficulties in managing the impacts of BIM, (4) Magnitude of change / staff turnover (roles and responsibilities issues), (5) Absence of other competing Initiatives, (6) Financial issues, (7) Construction insurance, (8) Lack of BIM experience (Know-how).this result is the same as the literature but their order is not.

6.4.6 Market barriers

This research agreed with the literature that the main market barriers are lack of publicity and awareness, and lack of client/government demand, however, there is a discrepancy about the readiness of the market. This research found that the KSA market is ready to implement BIM.

6.5 Removing the barriers

The interviewees suggested developing strategic plans relying on collaboration among government, private and public sectors to overcome all barriers. For instance, to overcome insufficient education and training software, providers could collaborate with government, entities, and university to educate and well train employees (short-term removing the barrier) and university students (long-term solution) to respond needs of BIM experts. This part is not found in the literature.

6.6 Key factors influence the adoption

Failure to adopt the change to BIM would result in loss of competitive advantage and accordingly fewer chances to win new projects (Mitropoulos & Tatum, 2000). Developing countries' governments must keep up with the development of the other developed countries which represent a pressure factor to mandate the latest

technology like BIM. This pushes organisation to preserve themselves surviving and implementing BIM.

6.6.1 External push

The questionnaire respondents and interviewees ordered the main External factors influencing the BIM implementations as : (1) Providing guidance on using BIM, (2) Government support and pressure for the implementation of BIM, (3) Providing education at university level, (4) Developing BIM and data exchange standards, rules and regulations, (5) Perceived benefits from BIM to client (6) Collaboration with universities (Research collaboration and curriculum design for students), (7) BIM required by other project parties, (8) Client pressure and demanding for the application of BIM in their projects, (9) Clients provide pilot project for BIM, (10) Contractual arrangements, (11) Promotion and awareness of BIM,(12) Competitive pressure, (13) Availability of appropriate software and hardware. This result is the same as the literature, but factors are ordered differently.

6.6.2 Internal push

Unlike the literature, interviewees and questionnaire respondents in this study respectively ordered the internal push factors as (1) Top management support, (2) Cultural change, (3) Perceived benefits from BIM, (4) BIM training program to staff, (5) Improving built output quality, (6) Continuous investment in BIM, (7) Desire for innovation with competitive advantages and differentiation in the market, (8) Technical competence of staff, (9) Financial resources of organization, (10) Improving the capacity to provide whole-life value to client, (11) Safety into the construction process (reduce risk of accident), (12) Collaboration among all project parties, (13) Projects complexity and profit declination. This result is with the line of the literature, but the factors are ordered differently.

6.7 Final methodology for implementing BIM

The interviewees validate the conceptual methodology and suggested the suitable order for its step which in turn results in the final methodology for implementing BIM as shown in figure (68). The interviewees confirm that, however, the main factor for rapid BIM implementation in KSA is the collaboration among different parties the government, the organizations (client, designer, contractor, subcontractor, suppliers) and every project stockholders, the main role is derived from the government since if the government mandates BIM, all parties will be committed to the change. The same way worked for advanced countries in mandating BIM.

Therefore, to implement the suggested methodology, it is claimed that the government must mandate BIM and other AEC industry stockholders collaborate with the government for successful implementation.

The suggested methodology consisted of six step the first is raising the BIM awareness, the second step is to identify the perceived benefits for each party, studying the AEC industry readiness and the organizations capabilities, identified the barriers, suggested strategic plans to remove those barriers, while the key factors influencing the BIM implementation play the role of the motivating factor and push each step (not as just a separated step). The interviewees claimed that the methodology must be practical as a cyclical process, not a linear one.

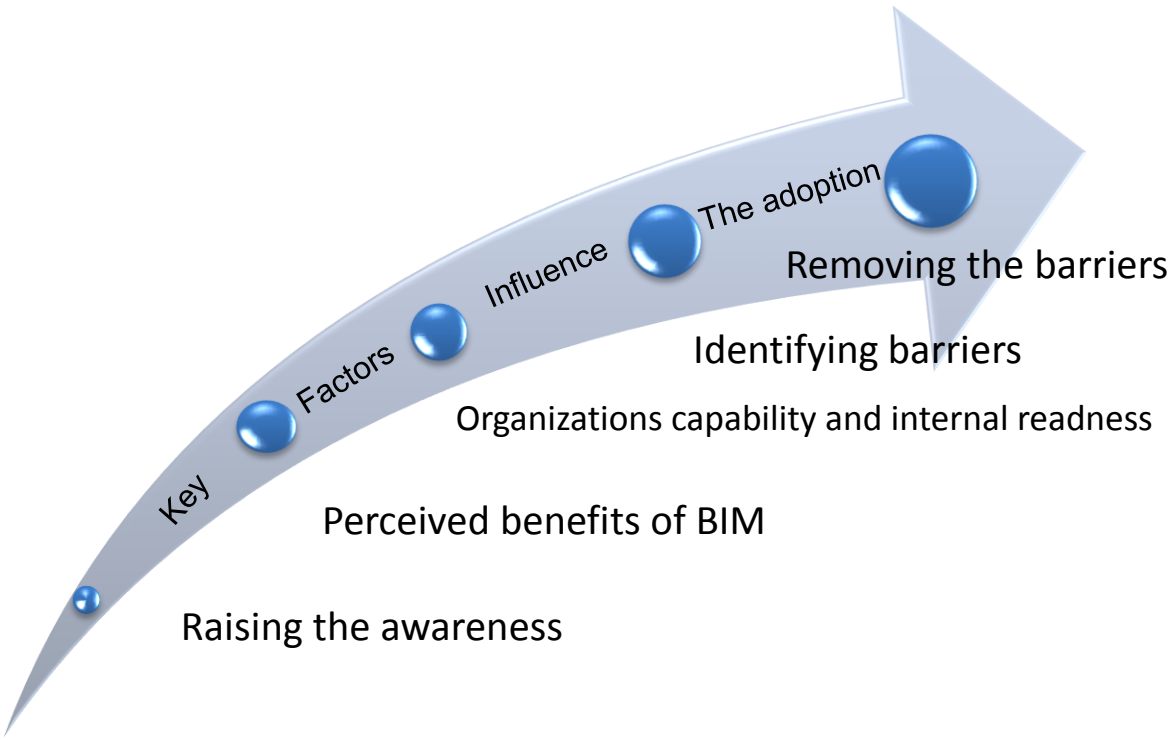

Figure 68: Final Methodology for implementing BIM

This study recommends applying mixed approach (top-down and bottom-up) to expedite and effectively implement the suggested methodology. Therefore, all AEC industry projects parties must collaborate and combine the efforts. The government of KSA can play a massive role to present convenient practical strategic plans for BIM implementation by providing a timeframe to mandate BIM as an obligatory requirement in the AEC industry projects. Also, the government could support the entities to overcome the barriers that hinder the BIM implementation. For instance, the government can aid entitles to overcome the initial BIM implementation cost. Involvement of BIM in the AEC undergraduate and postgraduates' syllabuses seems to be a premise in raising new generations fully oriented with BIM (long-term). Organizational decision makers have to support the staff (for example train the staff (short term), and put strategic plans to implement BIM. Every individual has to improve his BIM competencies.

These results help every project parties to be highly aware of BIM and understand its benefits, barriers and the main push factors to implement BIM. The study answers most of the question could be raised about BIM such as what BIM is, why it is mandatory, how BIM could be implemented? Who can do what related to BIM?

Applying the suggested methodology ensures the success of the BIM implementation which in turn improve the AEC industry performance and effectiveness, solving the project's issues, adapt the creativity and innovation and create unexpected stunning future for AEC industry

Suggestions for future research develop detailed, separate and special models for implementing BIM in KSA for each project parties client, architectural & designer, contractor, and subcontractor. Deriving models from the offered model in this research is to develop a short-term model and long-term model.

Limitation and assumptions of research

There is a difficulty to collect information for construction industry in KSA because of large area 2,149,690 square meter has different areas each area has its specific cultural nature for example, Riyadh city is different from Najran city, so there is not enough time to collect a large number of questionnaires or interviews from different area around the whole country to provide an integrated image for construction industry in KSA.

The research is limited to:

- The illustrated scope of this research (section 1.7)
- The influence of corruption is not considered.
- The influence of political impact is not fully estimated.
- Duration of the research is a few months.

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Appendix 1: Developing the Model Questionnaire survey

BIM in KSA: Analysis and Main Factors Influencing The Adoption

Ladies and gentlemen,
Greetings to all,
The following questionnaire targets to investigate the benefits, barriers and the main factors influencing the adoption of Building Information Modeling (BIM) in Kingdom of Saudi Arabia (KSA) in construction industry, it is a part of my dissertation required for MSc. Degree in Construction Project Management from Edinburgh Napier University, UK.
The collected information from this questionnaire will be used for scientific research only. Therefore, I am looking for your assistance to collaborate with each other to make an immense contribution in developing the efficiency of projects in developing country especially in KSA and maintaining continuous improvement, by exploiting the benefits of BIM to keep up with the developed countries. So, this is the time to build our future by filling this questionnaire. You are kindly requested to reply the following questions with Level of accuracy. Thanks a lot for your highly appreciated support.

Sincerely
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General Information

1. **What is your Organization Sector?** * *Mark only one oval.*

- ◯ Public
- ◯ Private

2. Which of the following best describes the principal industry of your organization? * *Check all that apply.*

- ☐ Residential
- ☐ Commercial
- ☐ Industrial
- ☐ Health-care
- ☐ Environmental
- ☐ infrastructure

- Academic
- Other:

3. **Number of Organization Employees?** * *Mark only one oval.*

- 1-30
- 31-60
- 61-100
- 101-200
- Over 200 Employees

4. **What is your project budget in SAR?** * *Mark only one oval.*

- Less than 50 M
- (Million) 51-100 M
- 101-200 M
- 201-500 M
- 501 M-1B
- More than 1B(Billion)

5. **Your Position in your Company?** * *Mark only one oval.*

- Director/ Vice
- Upper manager
- Project/section manager
- Designer Engineer
- Technical Office Engineer
- Construction Engineer
- Architect
- BIM manager
- BIM Designer
- Researcher / Academic
- Other:

6. **What is your education Level?** * *Mark only one oval.*

- BSc
- MSc
- PhD
- Other:

7. **Years of experience in the construction industry?** * *Mark only one oval.*

- Less than 5 yrs.
- 5-10 yrs.
- 11-15 yrs.

- 16-20 yrs.
- More than 20 years

8. Which region your project located in? * *Mark only one oval.*

- Qassim
- Riyadh
- Tabuk
- Madinah
- Makkah
- Northern Borders
- Jawf
- Ha'il
- Bahah
- Jizan
- 'Asir
- Najran
- Eastern Province
- Other

9. **How far are you knowledgeable about BIM?** * *Mark only one oval.*

- Not interesting *Skip to question 17.*
- Not using BIM but intend to use *Skip to question 18.*
- BIM user
- BIM expert
- BIM researcher
- Other:

Your BIM information

10. Which BIM Software does your Company use? * *Check all that apply*

- Revit
- Archi CAD
- Vico
- Bentley
- Vector Works
- Naviswork
- Tekla Structures
- Other:

11. What are the BIM applications? * *Check all that apply.*

- Interaction with non-professionals
- Design analysis
- Drawing production
- Project scheduling (programming)

- ◯ Cost estimating
- ◯ Tendering
- ◯ Quantity Surveying
- ◯ Site layout planning
- ◯ support constructability and analysis
- ◯ Collaboratively created, shared, and maintained models across the project lifecycle
- ◯ Safety (training and education, design , planning , accident investigation, and facility and Maintenance phase)
- ◯ Other:

12. Which of the following would be beneficial integrating with BIM? ***Check all that apply.***

- ☐ Lean construction
- ☐ Geography information system (GIS)
- ☐ Enterprise Resource Planning (ERP)
- ☐ Virtual Reality
- ☐ Facility Maintenance
- ☐ Integrated Project Delivery (IPD)
- ☐ Project Management
- ☐ Augmented reality for interactive architectural visualization
- ☐ Computer-aided facility management (CAFM)
- ☐ Health and Safety
- ☐ Green Building
- ☐ Construction Management Education
- ☐ Other:

13. What are the current BIM Maturity Levels in your project? *

Mark only one oval.

- ◯ Level 0 (Unmanaged CAD -2D)
- ◯ Level 1 (Managed CAD -Models are not shared- 3D)
- ◯ Level 2 : proprietary BIM (Managed 3D CAD-collaborative working)
- ◯ Level 3 :integrated BIM (4D, 5D, 6D)
- ◯ Level 4 (improved social outcomes and wellbeing)

14. What is the current implementing Dimension of BIM in your project?* *Mark only one oval.*

- ◯ 3D
- ◯ 4D
- ◯ 5D
- ◯ 6D
- ◯ 7D

15. What do you think about the future of BIM in KSA? ***Mark only one oval.***

- ◯ Not using BIM

- ◯ Increasing using BIM
- ◯ Top management mandate BIM
- ◯ Other:

16. Your experience as? * *Mark only one oval.*

- ◯ Owner / Client *Skip to question 20.*
- ◯ Designer / Architect / Engineer *Skip to question 22.*
- ◯ General Contractor *Skip to question 24.*
- ◯ Sub-Contractor *Skip to question 24.*
- ◯ Consulting *Skip to question 20.*
- ◯ Different experiences (client and contractor or client, designer and contractor, etc...) *Skip to question 20.*
- ◯ Research *Skip to question 20.*
- ◯ Other: *Skip to question 20.*

Skip to question 20.

17. Kindly please, explain the Reasons for being not interested in BIM?

18. Kindly please, explain why do you intend to use BIM?

19. Do you have the enough knowledge to provide us with benefits, barriers and Main Factors Influencing the Adoption of BIM? * *Mark only one oval.*

- ◯ Yes, continue answering the questions *Skip to question 20.*
- ◯ No, Finish the Questionnaire *Stop filling out this form.*

20. To what extent do you agree with the following benefits of BIM from Client perspective? * *Mark only one oval per row.*

	1- Strongly disagree	2- Disagree	3- Neutral	4- Agree	5- Strongly agree
Ensuring Project Requirements					
Enabling several marketing techniques: by the availability of high resolution rendering, animations & walkthroughs					
Evaluating project performance & maintenance: by enabling operation simulation					
Reducing financial risk: by reducing change orders& accurate cost estimation					

21. Your opinion about other benefits of BIM from a Client perspective?

22. To what extent do you agree with the following benefits of BIM from Designer perspective? * *Mark only one oval per row.*

	1- Strongly disagree	2- Disagree	3- Neutral	4- Agree	5- Strongly agree
Producing Various design options					
Facilitating visual evacuation plans, safety analysis, etc.					
Enabling Sustainable analysis to predict environmental performance					
Extracting fast Issued for construction (IFC) drawings					

23. Your opinion about other benefits of BIM from a Designer perspective?

24. To what extent do you agree with the following benefits of BIM from Contractor perspective? * *Mark only one oval per row.*

	1- Strongly disagree	2- Disagree	3- Neutral	4- Agree	5- Strongly agree
Enable 3D Coordination					
Site Utilizing Planning					
Monitor & Control Progress					
Increase Health & Safety					
Accurate BOQ & Cost Estimation					
Information Integration					
Supporting construction and project management					
Staff recruitment and retention					
Enhanced ability to compete					
Automated assembly					

25. Your opinion about other benefits of BIM from a Contractor perspective?

26. To what extent do you agree with the following benefits of BIM to all the participants?

	1- Strongly disagree	2- Disagree	3- Neutral	4- Agree	5- Strongly agree
Time savings					
The cost reduction					
Improving the quality					
Clash detection					
Improves visualization: Reduced requests for information					
Enhance collaboration & communication					
Reduced Document Errors and omissions					
Reduced claim and law issues					
Reduce Waste and value generation					
Increasing efficiency					
Life cycle data					

27. Your opinion about other benefits of BIM to all participants?

28. To what extent do you agree with the following Barriers to BIM Adoption Personal Barriers?

	1- Strongly disagree	2- Disagree	3- Neutral	4- Agree	5- Strongly agree
Lack of insufficient training					
Lack of understanding of BIM and its benefits					
Resistance to change: Lack of skills development					
Lack of BIM education					
Lack of BIM knowledge in applying current technologies					

29. What is your opinion about the Personal Barriers (please specify)?

**30. BIM Process Barriers ***_Mark only one oval per row._

	1- Strongly disagree	2- Disagree	3- Neutral	4- Agree	5- Strongly agree
Legal issues (ownership of data)					
Risks and challenges with the use of a single model (BIM)					
Changing work processes (Lack of effective collaboration among project participants)					

31. What is your opinion about the other Process Barriers (please specify)?

32. Business Barriers * _Mark only one oval per row_

	1- Strongly disagree	2- Disagree	3- Neutral	4- Agree	5- Strongly agree
High Cost of implementation					
Unclear benefits					
Doubts about Return on Investment (ROI)					
Lack of contractual arrangements: The changing roles, responsibilities and payment arrangements					
Time and Cost of training					
Complicated and time consuming modelling process					
Time and Cost of training					

33. What is your opinion about the other Business Barriers (please specify)?

34. Technical Barriers * *Mark only one oval per row*

	1- Strongly disagree	2- Disagree	3- Neutral	4- Agree	5- Strongly agree
Lack of BIM technical experts					
Interoperability					
Absence of standards and clear guidelines					
Insufficient technology infrastructure					
Current technology is enough					

35. What is your opinion about the other Technical Barriers (please specify)?

36. Organization Barriers * *Mark only one oval per row*

	1- Strongly disagree	2- Disagree	3- Neutral	4- Agree	5- Strongly agree
Lack of Senior Management support.					
Difficulties in managing the impacts of BIM					
Absence of Other Competing Initiatives					
Unwillingness to change					
Magnitude of Change / Staff turnover					
Construction Insurance companies issues					

37. What is your opinion about the other Organization Barriers (please specify)?

38. Market Barriers * *Mark only one oval per row*

	1- Strongly disagree	2- Disagree	3- Neutral	4- Agree	5- Strongly agree
Lack of client/government demand					
The market is not ready yet					
Lack of publicity and awareness					

39. Your opinion about the other Market Barriers (please specify)?

40. To what extent do you agree with the following External Push **Mark only one oval*

	1- Strongly disagree	2- Disagree	3- Neutral	4- Agree	5- Strongly agree
Government support and					
pressure in the implementation of BIM					
Client pressure and demand					
Provide education at university level					
Developing BIM standards					
Providing guidance on use of BIM					
contractual arrangements					
BIM required by other project parties					
Competitive pressure					
Promotion and awareness of BIM					
Clients provide pilot project for BIM					
Collaboration with universities					
Perceived benefits from BIM to client					

41. What is your opinion about Other External Push?

42. Internal Push for Implementing BIM in KSA * *Mark only one oval per row*

	1- Strongly disagree	2- Disagree	3- Neutral	4- Agree	5- Strongly agree
Top management support					
Cultural change					
Improving built output quality					
Perceived benefits from BIM					
Technical competence of staff					
Financial resources of organization					
Desire for competitive advantages					
Improving the capacity to provide whole-life value to client					
Safety into the construction process accident) (reduce risk of					
BIM training program to staff					
Requirement for staff to be BIM competent					
Continuous investment in BIM					

43. What is your opinion about Other Internal Push for Implementing BIM in KSA (Please specify)?

44. Kindly Please provide us with any information or advice you think that it will help this research?

Appendix 2 Developing the Model Interviews

NO.	interviewers
1	Engr. Hani Salah Omar, PhD student-BIM, MSc-BIM, BIM specialist ,BIM instructor
2	Engr. Omer Selim, Founder of BIMarabia Magazine|BIM Manager|RICS|BIM Implementation Expert| Autodesk Certified Instructor
3	Engr. Mohammad El Yamani, Projects Director,BIM manager
4	Waleed Mohamed Nasar, PhD,BIM Manager
5	Hamzza Mishref, PhD student-BIM, MSc-BIM
6	Mohamed ElSaadany, PMP, CCP, PMI-RMP, SCE-PE
7	Mohamed (El Sayed) Younis, BSc., PRMG, MSc.
8	Tae Yeual, (BIM Specialist) PMP®, PE®, LEED® APs
9	Eng.Bassant Sarhan
10	Islam Hassan, Project Manager, MSc - BIM, PMI-PMP, El-Seif Contracting Company - AlRriyadh Metro
11	Eng. Ahmed Ramadan
12	WALEED MAHFOUZ , PhD, MSc, BSc-Eng. Civil, PMP
13	Emad Aref mostafa,BIM manager at BIM-KSA Engineering Consulting Group
14	Salma Mohsen, BIM Structural Engineer/ instructor
15	Mohamed Elmasri, BIM Unit Team Leader
16	Taher Saied, CAD MASTERS founder -Architect - Autodesk Certified Instr.- Member AIA&LPI - Executive Management AUC
17	Abdelrahman, MSc-BIM
18	Hani El Gharib Hadhood, Senior Designer Architect / Interior Director | BIM
19	Ibrahim Sabry, Revit Specialist
20	Salah Omar Omran, Egyptian Civil Engineer, PHD Candidate, MSC, Autodesk certified instructor, ACP Revit Str, Arch
21	Kamel Al-Shaikhli, Editor at BIMarabia
22	Sonia Ahmed, Editor at BIMarabia
23	Abdulaziz Banawi, Ph.D., USGBC Faculty Member, BPA, LEED Green Associate,US Green Building Council, BIM author
24	Jorge Cayetano Pignataro, BIM specialist
25	Daniel Stonecipher, CEO at IMMERSIVx, BIM Chair and Immediate Past President at IFMA Information

The interview: Questions and Answers

The interview No1

Personal information

Question no. 1:

Could you introduce your-self, please?

Answer no. 1:

Engr. Hani Salah Omar, PhD student, MSc, in construction management and the dissertation topic was BIM. I have 20 year experience , working now as infrastructure specialist at DEWA past experience as Resident Engineer /Project Manager AECOM Middle East Ltd.& Parsons International Limited, BIM lecturer at The British University in Dubai, Studies my PhD at University of The West of England (UWE) Bristol, U.K. The PhD thesis concerns BIM, construction

automation and photogrammetry Studied Civil engineering at Ain Shams University, Faculty of Engineering.

BIM information

Question no. 2:

What is the definition of BIM?

Answer no. 2:

There are many definitions of BIM, however the one in my opinion is the most appropriate that is articulated by NBIMS (2010).

A digital representation of physical and function characteristics of facility. BIM is a shared knowledge resource of information about a facility forming a reliable basis for decisions during its lifecycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of stakeholders.

Question no. 3:

Which BIM Software does your Company use?

Answer no. 3:

Revit, Project wise

Question no. 4:

What are the BIM applications?

Answer no. 4:

Material take-off, Clash detection, Build-in code and specifications, Cost estimating, Project planning and construction monitoring, Sustainability analysis, Site logistics and safety management, Interaction with non-professionals, Design analysis, Drawing production, Project scheduling (programming), Cost estimating, , , Site layout planning, support constructability and analysis, , Safety (training and education) virtual reality and augmented reality.

Question no. 5:

Which of the following would be beneficial integrating with BIM?

Answer no. 5:

Lean construction, Geography information system (GIS), Enterprise Resource Planning (ERP), Virtual Reality, Facility Maintenance, Integrated Project Delivery (IPD), Project Management, Augmented reality for interactive architectural visualization, Computer-aided facility management (CAFM), Health and, Green Building, Construction Management Education, Just in Time Production (JIT), Total Quality Management and Six Sigma.

The Benefits of BIM

Question no. 6:

What is the Benefits of BIM according to Client perspective?

Answer no. 6:

Ensuring Project Requirements, Acquire competitive advantage, improve project performance & maintenance: by enabling operation simulation, Reducing financial risk: by reducing change orders& accurate cost estimation, Information Model, cut project cost , save time , improve the Quality , Effective Decision Making, improve safety measures acquire customer/end users satisfactions.

Question no. 7:

What is the Benefits of BIM according to Designer perspective?

Answer no. 7:

Error-free design (Low redesign), Clash detection, collaboration, fast decisions from the client, save time, Producing various design options, Facilitating visual evacuation plans, safety analysis, etc., Enabling Sustainable analysis to predict the asset/structure performance, collaboration through cloud servers broken the distance barriers, accordingly several designers can work collaboratively for the same project from different places around the world. Enhance competitions between designers. Designers are acquainted with the latest technologies as BIM evolving.

Question no. 8:

What is the Benefits of BIM in Contractor perspective?

Answer no. 8:

BIM offers improved productivity, boost profits Making profits, accurate quantity take-off, foster collaboration, cut cost, save time, improve Quality, Less rework, Enable 3D Coordination, Site Utilizing Planning, Improved logistics and machinery planning, Control of the site construction (Monitor & Control Progress), improve Health & Safety measures (Improve Safety management), Accurate BOQ & Cost Estimation, Information Integration, Supporting construction and project management (Improved performance of the Facility Management (FM)),

Enhanced ability to compete, Automated assembly (enhance Just in time to save time, cost and materiel), Reduction in wasted materials.

Question no. 9:

What is the Benefits of BIM in all participants' perspective?

Answer no. 9:

Time savings, the cost reduction, improving the quality and reduced rework, meet client satisfaction, early involvement of owners for quick decisions, clash detection, dramatically reduce variation orders and ROI, Improves visualization:, BIM offers Integration/collaboration and robust communication amongst different teams., reduced document errors and omissions, Reduce Waste, Reduced contractual claims and lawful issues, reduced disputes, Increased efficiency, Created an open common data environment (DCE) for sharing information. Throughout the project Life cycle, reliable sustainability analysis, promoted the off-site prefabrication (Precast concrete- etc.), document automation, fast and accurate production of As-Built drawings.

Question no. 10:

What is the Personal Barriers to BIM Adoption?

Answer no. 10:

Lack of insufficient training, lack of understanding of BIM and its benefits, resistance to change, lack of BIM education, lack of BIM knowledge in applying current technologies
Change resistance, poor change management model, lack of know-how, insufficient expertise pertaining to BIM. Fear of losing jobs, fear of the ability to learn new issues, uncertainty.

Question no. 11:

What is the Process Barriers to BIM Adoption?

Answer no. 11:

Legal issues (ownership of data), Risks and challenges with the use of a single model (BIM), Changing work processes (Lack of effective collaboration among project participants).

Question no. 12:

What is the Business Barriers to BIM Adoption?

Answer no. 12:

Lots of funding (high cost of implementation especially in the beginning), unclear benefits, doubts about return on Investment, Legal and contractual challenges (Unclear Intellectual Property Rights (IPR), AEC Traditional procurement methodology, lack of contractual arrangements: the changing roles, responsibilities and payment arrangements), time and cost of training, complicated and time-consuming modelling process. BIM reaps its utmost benefits if all stakeholders are using BIM however, BIM still in its embarking stage in MENA area. Accordingly, many organizations are reluctant to utilize BIM.

Question no. 13:

What is the Technical Barriers to BIM Adoption?

Answer no. 13:

Inadequate BIM experience (know-how) to change, lack of BIM technical experts, Interoperability issues, Difficulties correlated with managing BIM Model, absence of standards and clear guidelines, many managers claimed that the current technology is enough.

Question no. 14:

What is the Organization Barriers to BIM Adoption?

Answer no. 14:

Lack of Senior Management support, Difficulties in managing the impacts of BIM, Absence of Other Competing Initiatives, Unwillingness to change, Magnitude of Change / Staff turnover, funding issues.

Question no. 15:

What is the Market Barriers to BIM Adoption?

Answer no. 15:

The client/government is not requesting BIM as a compulsory requirement in the projects, the market is not ready yet, and lack of publicity and awareness, not all stakeholders are using BIM.

Main Factors Influencing the Adoption of BIM in KSA

Question no. 16:

What are the External Push for Implementing BIM in KSA?

Answer no. 16:

The government mandate BIM in its projects (Government support and pressure in the implementation of BIM), Client pressure and demand the application of BIM in their projects(Top-down approach), provide education at university level, Developing BIM data exchange standards, rules and regulations, providing guidance on use of BIM, provide contractual arrangements, BIM required by other project parties, Surrounding environment and competitive pressure, Projects complexity and profit declination, Promotion and awareness of BIM, clients provide pilot projects for BIM, collaboration with universities (Research collaboration and curriculum design for students), Perceived benefits from BIM to client,

Question no. 17:

What are the Internal Push for Implementing BIM in KSA?

Answer no. 17:

Organizational decision due to the recognized benefits of BIM, Top management support, Cultural change (Organization level of flexibility towards the change), BIM training program to staff, Improving built output quality, Perceived benefits towards BIM, Technical competence of staff, Financial resources of organization, Desire for innovation with competitive advantages and differentiation in the market., Improving the capacity to provide whole-life value to client, convince the client that benefits of BIM responding their needs and within their financial ability(bottom-up approach) , Safety into the construction process (reduce risk of accident), Requirement for staff to be BIM competent, Continuous investment in BIM

In my opinion, mixed approaches (Top-down & bottom-up) will help to accelerate the implementation of BIM in KSA.

Question no. 18:

What are the current BIM Maturity Levels in your project?

Answer no. 18:

Level 1 (Managed CAD -Models are not shared- 3D)

Question no. 19:

What do you think about the future of BIM in KSA?

Answer no. 19:

BIM will be mandated and will be the common practice all over the world in the coming 5 years including the KSA.

Question no. 20:

Do you want to add anything you think it will help to enhance implementing BIM in KSA?

Answer no. 20:

To enhance implementing BIM in KSA we have four step: the first is convince all participants about Perceived benefits of BIM the second is overcoming the Challenges& obstacles hinder implementation of BIM the third one is increasing the Driving forces/pressures of external push to implement BIM and increasing AEC Industry& organization internal readiness. The fourth is to create a knowledgeable generations by educating the under and post graduates in the engineering universities.

The interview No2

Personal information

Question no. 1:

Could you introduce your-self, please?

Answer no. 1:

Omer Selim, Co-Founder, Director at BIMarabia has 15 year experience , BIM Manager at UrbaCon General Contracting , BIM Coordinator at EHAF Consulting Engineers , BIM Specialist at Saudi Diyar Consultants, BIM Specialist at Signature Engineering Consultants S.E.C, CAD/BIM Specialist at Allied Consultants LTD, work many projects in Saudi Arabia.

BIM information

Question no. 2:

What is the definition of BIM?

Answer no. 2:

If you ask five people about BIM definition you will get six different answers, the definition which I have followed is set of techniques and methods of work. BIM is a process involving the generation and management of digital representations of physical and functional characteristics of places

Question no. 3:

Which BIM Software does your Company use?

Answer no. 3:

Revit, Archi CAD, Vico, Bentley, Vector Works, Naviswork, Tekla Structures

Question no. 4:

What are the BIM applications?

Answer no. 4:

Interaction with non-professionals, Design analysis, Drawing production, Project scheduling (programming), Cost estimating, Tendering, Quantity Surveying, Site layout planning, support constructability and analysis, Collaboratively created, shared, and maintained models across the project lifecycle and Safety (training and education, design , planning , accident investigation, and facility and maintenance phase)

Question no. 5:

Which of the following would be beneficial integrating with BIM?

Answer no. 5:

Lean construction, Geography information system (GIS), Enterprise Resource Planning (ERP), Virtual Reality, Facility Maintenance, Integrated Project Delivery (IPD), Project Management, Augmented reality for interactive architectural visualization, Computer-aided facility management (CAFM), Health and, Green Building, Construction Management Education, Just in Time Production, Total Quality Management and Six Sigma

The Benefits of BIM

Question no. 6:

What is the Benefits of BIM in Client perspective?

Answer no. 6:

Ensuring Project Requirements, Acquire competitive advantage, Evaluating project performance & maintenance: by enabling operation simulation, Reducing financial risk: by reducing change orders& accurate cost estimation, Information Model, cut project cost , save time , improve the Quality , Effective Decision Making

Question no. 7:

What is the Benefits of BIM in Designer perspective?

Answer no. 7:

Error-free design (Low redesign), Clash detection, collaboration, fast decisions from the client, save time, Producing various design options, Facilitating visual evacuation plans, safety analysis, etc., Enabling Sustainable analysis to predict environmental performance, Extracting fast Issued for construction (IFC) drawings,

Question no. 8:

What is the Benefits of BIM in Contractor perspective?

Answer no. 8:

Make profits, collaboration, cut cost, save time, improve Quality, Enable 3D Coordination, Site Utilizing Planning, Control of the site construction (Monitor & Control Progress), Increase Health & Safety (Improve Safety management), Accurate BOQ & Cost Estimation, Information Integration, Supporting construction and project management (facility management), Enhanced ability to compete, Automated assembly (enhance Just in time to save time, cost and materiel)

Question no. 9:

What is the Benefits of BIM in all participants' perspective?

Answer no. 9:

Time savings, The cost reduction, Improving the quality and Reduced Rework, Meet client satisfaction, Clash detection, Improves visualization: Reduced Number of requests for information, Need for Information Requests and change orders, Enhance collaboration & communication, Reduced Document Errors and omissions, Reduce Waste and value generation, Reduced claim and law issues, Increasing efficiency, Creation and sharing of information ability: Life cycle data, Reliable sustainability analysis

Question no. 10:

What is the Personal Barriers to BIM Adoption?

Answer no. 10:

Lack of insufficient training, lack of understanding of BIM and its benefits, resistance to change: lack of skills development, lack of BIM education, lack of BIM knowledge in applying current technologies

Question no. 11:

What is the Process Barriers to BIM Adoption?

Answer no. 11:

Legal issues (ownership of data), Risks and challenges with the use of a single model (BIM), Changing work processes (Lack of effective collaboration among project participants).

Question no. 12:

What is the Business Barriers to BIM Adoption?

Answer no. 12:

Lots of funding (high cost of implementation), unclear benefits, doubts about return on Investment, lack of contractual arrangements: the changing roles, responsibilities and payment arrangements, time and cost of training, complicated and time-consuming modelling process

Question no. 13:

What is the Technical Barriers to BIM Adoption?

Answer no. 13:

Know How, Lack of BIM technical experts, Interoperability, Absence of standards and clear guidelines, insufficient technology infrastructure, Current technology is enough

Question no. 14:

What is the Organization Barriers to BIM Adoption?

Answer no. 14:

Lack of Senior Management support, Difficulties in managing the impacts of BIM, Absence of Other Competing Initiatives, Unwillingness to change, Magnitude of Change / Staff turnover,

Question no. 15:

What is the Market Barriers to BIM Adoption?

Answer no. 15:

The client/government is not requesting BIM as a compulsory requirement in the projects, the market is not ready yet, Lack of publicity and awareness,

Main Factors Influencing the Adoption of BIM in KSA

Question no. 16:

What are the External Push for Implementing BIM in KSA?

Answer no. 16:

The government mandate BIM in its projects (Government support and pressure in the implementation of BIM), Client pressure and demand the application of BIM in their projects(Top-down approach), provide education at university level, Developing BIM data exchange standards, rules and regulations, providing guidance on use of BIM, provide contractual arrangements, BIM required by other project parties, Competitive pressure, Promotion and awareness of BIM, clients provide pilot project for BIM, collaboration with universities (Research collaboration and curriculum design for students), Perceived benefits from BIM to client,

Question no. 17:

What are the Internal Push for Implementing BIM in KSA?

Answer no. 17:

Top management support, Cultural change, BIM training program to staff, Improving built output quality, Perceived benefits from BIM, Technical competence of staff, Financial resources of organization, Desire for innovation with competitive advantages and differentiation in the market., Improving the capacity to provide whole-life value to client, convince the client that benefits of BIM responding their needs and within their financial ability(bottom-up approach) , Safety into the construction process (reduce risk of accident), Requirement for staff to be BIM competent, Continuous investment in BIM

In my opinion, mixed approaches (Top-down & bottom-up) will help to implement BIM in KSA faster.

Question no. 18:

What are the current BIM Maturity Levels in your project?

Answer no. 18:

Level 1 (Managed CAD -Models are not shared- 3D)

Question no. 19:

What do you think about the future of BIM in KSA?

Answer no. 19:

Top management mandate BIM

Question no. 20:

Do you want to add anything you think it will help to enhance implementing BIM in KSA?

Answer no. 20:

Use BIM to save the raw materials for future generations

Appendix 3: Model validation Questionnaire survey

General Information

1. What is your Organization Sector? * *Mark only one oval.*

- ◯ Public
- ◯ Private

2. Which of the following best describes the principal industry of your organization? * *Check all that apply.*

- ☐ Residential
- ☐ Commercial
- ☐ Industrial
- ☐ Health-care
- ☐ Environmental
- ☐ infrastructure
- ☐ Academic
- ☐ Other: _____

3. Number of Organization Employees? * *Mark only one oval.*

- ◯ 1-30
- ◯ 31-60
- ◯ 61-100
- ◯ 101-200
- ◯ Over 200 Employees

4. What is your project budget in SAR? * *Mark only one oval.*

- ◯ Less than 50 M
- ◯ (Million) 51-100 M
- ◯ 101-200 M
- ◯ 201-500 M
- ◯ 501 M-1B
- ◯ More than 1B(Billion)

5. Your Position in your Company? * *Mark only one oval.*

- ◯ Director/ Vice
- ◯ Upper manager
- ◯ Project/section manager
- ◯ Designer Engineer
- ◯ Technical Office Engineer
- ◯ Construction Engineer
- ◯ Architect
- ◯ BIM manager
- ◯ BIM Designer
- ◯ Researcher / Academic
- ◯ Other: _____

6. **What is your education Level?** * *Mark only one oval.*

- ◯ BSc
- ◯ MSc
- ◯ PhD
- ◯ Other: _____

7. **Years of experience in the construction industry?** * *Mark only one oval.*

- ◯ Less than 5 yrs.
- ◯ 5-10 yrs.
- ◯ 11-15 yrs.
- ◯ 16-20 yrs.
- ◯ More than 20 years

8. **To what extent do you agree that the following Factors impact the Implementation of BIM in KSA AEC industry? *** *Mark only one oval per row*

	1- Strongly disagree	2- Disagree	3- Neutral	4- Agree	5- Strongly agree
Raising awareness					
Perceived benefits of BIM					
Identifying barriers (first step					
for plan to remove it)					
Removing the barriers					
Key Factors influence the					

Appendix 4 Model validation Interviews

The interviewees list required to answer the same of the Model validation questionnaire and their perspective about the detailed conceptual models

No.	Interviewees	No.	Interviewees
1	Eng. Ayman Kandeel ,BIM specialist	26	Ahmed Nabil , BIM manger
2	Mohamed Elsayed (BIM, PMP)	27	Khalid Saad , BIM manger
3	Stephen Au, Managing Director at MTECH Engineering Co, BIM manager	28	AL said Abo Alnaga, BIM manger
4	Balaji Saravanan, Program Manager,BIM specialist	29	Parveen Sharma, MSc, BIM/VDC/IPD Specialist
5	Amr Riyaza, Revit specialist	30	Karen Fugle, Executive Coaching for Architects & Designers, BIM consultant
6	Brent Mauti, BIM Specialist	31	Juan Guzman, Engineering Training & Development Consultant, BIM instructor
7	Allard Leenaerts, BIM modeler at VK Architects & Engineers	32	Bruno Soares de Carvalho, PhD Student | Commercial and Engineering Manager
8	Antonio Soriano de Aza, BIM Construction Manager	33	Hector Camps, Building Smart Alliance, Master of Architecture
9	Kurt Metcalfe, Principal Architectural Engineer at Cavendish Nuclear	34	Bilal Succar, PhD, BIM key author
10	Italo Enrique León Santamaria, Architect specializing in sustainable architecture and BIM Coordination	35	Raul Ceballos Gamboa, BIM Estimator in Pacific Structures

11	Sonia Ahmed, BIMarabia, PhD student	36	Mohamed Hussein,
12	William Sosa de León, Autodesk Certified in several BIM and CAD Information Technology Solutions	37	Peter Cholakis, Senior Vice President at Four BT, LLC
13	Regina Ruschel, PhD, BIM specialist	38	Per David Sannes, BIM Protagonist
14	vinod desu, Revit Modular (HVAC) / Services Coordinator	39	Suryakanta Kabi, BIM/GIS/VDC Program Management, Digital Engineering
15	Fábio Gomes, Technical Account Manager at Autodesk Inc	40	Stephen Au, Managing Director at MTECH Engineering Co, MBA, MSc, BIM manager
16	Saeid Khalili Ghomi, BIM consultant	41	Patrick Baur, BIM Specialist
17	Woon Wei PONG, BIM consultant	42	Mohd Faiz Shapiai, BIM Specialist
18	JUNGHWO PARK, BIM Manager at Boris Podrecca Architects	43	Javier Meléndez, Designer & BIM Specialist
19	Mandar Jadhav, CEO @ Scale |Multidisciplinary Engineering|BIM-Resource Center Implementation	44	Rene Meijer, Trainee BIM
20	Arthur TRANCHANT, BIM specialist	45	Said Bensaad, PhD, BIM Specialist
21	Philippe Steiner, Chef de projet développement CCHE / Head of BIM CCHE	46	Mohamad Kassem, PhD, BIM author
22	Sylvain RISS, BIM instructor	47	Arkadiusz Gacki, Design/ Technical Manager - Precast and Civil Structures
23	Bassam kamal, Technical Office Architect at Sabbour consultant bureau	48	Alberto Tono, BIM Research & Development
24	Ibrahim Elmeligy, Lecturer & BIM Architect	49	Kamal Aweisat, phD, Senior Project Manager at Construction Consulting
25	Basavaraj Hallur, BIM BOSS CONSULTANTS	50	Ahmed Nabil , BIM manger

Appendix 5 Different between user and not use BIM perspective

This study agree with (Giligan & Kunz, 2007).There is discrepancies among the perceptions and desires of non-users and those of users. The interviewees who use BIM as their high knowledge about BIM provide more benefits , main barriers to implement BIM and the factors influencing the implementation however the interviewees who nonuse BIM cannot provide benefits they (how they know) can report why they don't use BIM and suggest factors motivate them to implement BIM. The following tables compere among BIM user and BIM non user perspectives about Perceived BIM benefits, barriers to BIM implementation, main factors influencing the implementation

Perceived BIM benefits

Client perspective

Ensuring Project Requirements

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	0	1	0	3
Disagree	1	0	1	1	3
Neutral	9	1	1	3	14
Agree	23	3	5	6	37
Strongly agree	11	12	9	9	41
Total	45	16	17	19	98

Enabling several marketing techniques

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	0	1	0	2
Disagree	4	0	0	0	4
Neutral	11	3	4	3	22
Agree	19	3	7	8	37
Strongly agree	10	10	5	8	33
Total	45	16	17	19	98

Evaluating project performance & maintenance

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	0	0	1	1	2
Disagree	3	0	1	0	4
Neutral	9	1	2	2	15
Agree	18	5	4	7	34
Strongly agree	15	10	9	9	43
Total	45	16	17	19	98

Reducing financial risk

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	0	1	0	2
Disagree	3	0	1	1	6
Neutral	9	1	0	1	11
Agree	14	4	6	7	31
Strongly agree	18	11	9	10	48
Total	45	16	17	19	98

Information Model

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	0	0	1	0	1
Disagree	4	0	0	0	5
Neutral	5	1	1	1	8
Agree	18	3	6	5	32
Strongly agree	18	12	9	13	52
Total	45	16	17	19	98

Designer perspective

Producing various design options

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	0	1	0	2
Disagree	8	3	1	1	14
Neutral	11	4	2	1	18
Agree	16	12	8	11	47
Strongly agree	9	16	13	10	48
Total	45	35	25	23	129

Safety Plan & analysis

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	0	1	0	2
Disagree	2	2	0	0	4
Neutral	9	4	5	2	20
Agree	20	17	12	11	61
Strongly agree	13	12	7	10	42
Total	45	35	25	23	129

Enabling Sustainable analysis

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	1	1	0	3
Disagree	3	0	2	0	5
Neutral	10	10	6	3	30
Agree	23	9	5	8	45
Strongly agree	8	15	11	12	46
Total	45	35	25	23	129

Extracting fast IFC drawings

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	0	1	0	2
Disagree	3	0	0	0	3
Neutral	5	2	6	4	17
Agree	15	14	9	10	49
Strongly agree	21	19	9	9	58
Total	45	35	25	23	129

Contractor perspective

Enable 3D Coordination

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	0	0	2	0	3
Disagree	1	4	0	1	6
Neutral	7	5	2	4	18
Agree	11	8	9	9	37
Strongly agree	26	31	21	11	89
Total	45	48	34	25	153

Site Utilizing Planning

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	0	1	2	0	3
Disagree	2	5	0	1	8
Neutral	12	9	5	3	30
Agree	15	13	14	9	51
Strongly agree	16	20	13	12	61
Total	45	48	34	25	153

Monitor & Control Progress

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	0	2	0	3
Disagree	1	2	0	0	3
Neutral	15	14	4	3	36
Agree	15	13	16	9	54
Strongly agree	13	19	12	13	57
Total	45	48	34	25	153

Increase Health & Safety

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	1	2	0	5
Disagree	5	5	2	2	14
Neutral	19	16	10	9	54
Agree	13	11	12	6	42
Strongly agree	6	15	8	8	38
Total	45	48	34	25	153

Accurate BOQ & Cost Estimation

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	0	2	0	4
Disagree	2	5	1	0	8
Neutral	8	6	3	3	20
Agree	14	14	12	8	49
Strongly agree	19	23	16	14	72
Total	45	48	34	25	153

Information Integration

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	2	2	0	5
Disagree	1	2	2	1	6
Neutral	6	7	2	1	17
Agree	13	15	11	10	49
Strongly agree	24	22	17	13	76
Total	45	48	34	25	153

Supporting construction and project management

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	0	2	0	3
Disagree	2	6	1	0	9
Neutral	8	8	3	4	24
Agree	17	12	12	6	47
Strongly agree	17	22	16	15	70
Total	45	48	34	25	153

Staff recruitment and retention

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	2	4	2	10
Disagree	5	7	4	1	18
Neutral	18	17	11	9	55
Agree	12	9	10	6	37
Strongly agree	8	13	5	7	33
Total	45	48	34	25	153

Enhanced ability to compete

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	2	2	0	5
Disagree	3	4	0	2	10
Neutral	11	5	6	5	27
Agree	16	18	15	9	58
Strongly agree	14	19	11	9	53
Total	45	48	34	25	153

Automated assembly * Knowledgeable about BIM

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	1	3	0	5
Disagree	2	4	1	1	9
Neutral	11	11	6	5	33
Agree	17	16	12	11	56
Strongly agree	14	16	12	8	50
Total	45	48	34	25	153

Shared benefits (to all participants)

Time savings

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	3	1	0	5
Disagree	4	3	1	0	9
Neutral	5	2	2	3	12
Agree	15	16	12	8	51
Strongly agree	20	24	18	14	76
Total	45	48	34	25	153

The cost reduction

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	3	2	0	6
Disagree	5	2	2	0	10
Neutral	7	4	1	3	15
Agree	14	17	10	10	51
Strongly agree	18	22	19	12	71
Total	45	48	34	25	153

Improving the quality and Reduced Rework

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	3	4	1	0	8
Disagree	1	0	2	0	4
Neutral	4	3	1	6	14
Agree	19	15	11	7	52
Strongly agree	18	26	19	12	75
Total	45	48	34	25	153

Clash detection

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	3	2	1	0	6
Disagree	3	3	1	1	9
Neutral	5	5	1	1	12
Agree	11	8	6	8	33
Strongly agree	23	30	25	15	93
Total	45	48	34	25	153

Improves visualization

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	3	1	1	7
Disagree	3	4	1	1	10
Neutral	5	3	4	3	15
Agree	20	17	11	8	56
Strongly agree	15	21	17	12	65
Total	45	48	34	25	153

Reduced Number of requests for information

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	3	1	1	7
Disagree	3	4	1	1	10
Neutral	5	3	4	3	15
Agree	20	17	11	8	56
Strongly agree	15	21	17	12	65
Total	45	48	34	25	153

Reduced change orders

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	3	1	1	7
Disagree	3	4	1	1	10
Neutral	5	3	4	3	15
Agree	20	17	11	8	56
Strongly agree	15	21	17	12	65
Total	45	48	34	25	153

Enhance collaboration & communication

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	3	1	0	5
Disagree	5	1	1	0	8
Neutral	4	9	2	2	17
Agree	18	14	8	10	50
Strongly agree	17	21	22	13	73
Total	45	48	34	25	153

Reduced Document Errors and omissions

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	4	1	0	6
Disagree	3	2	2	0	8
Neutral	9	1	3	4	17
Agree	17	18	12	8	55
Strongly agree	15	23	16	13	67
Total	45	48	34	25	153

Reduced claim and law issues

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	2	1	0	4
Disagree	4	4	3	0	12
Neutral	10	9	9	5	33
Agree	19	16	7	9	51
Strongly agree	11	17	14	11	53
Total	45	48	34	25	153

Reduce Waste and value generation

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	0	4	2	0	6
Disagree	4	3	2	1	11
Neutral	11	6	4	3	24
Agree	15	15	9	12	51
Strongly agree	15	20	17	9	61
Total	45	48	34	25	153

Increasing efficiency

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	2	1	0	4
Disagree	5	4	3	0	12
Neutral	5	2	2	2	12
Agree	17	14	9	8	48
Strongly agree	17	26	19	15	77
Total	45	48	34	25	153

Creation and sharing of information ability: Life cycle data

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	4	1	0	7
Disagree	3	2	2	0	7
Neutral	7	6	3	4	21
Agree	17	15	8	4	44
Strongly agree	16	21	20	17	74
Total	45	48	34	25	153

Identified the Barriers

Personal Barriers

Lack of insufficient training

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	1	3	0	6
Disagree	4	3	2	1	11
Neutral	9	11	4	3	27
Agree	14	16	15	5	50
Strongly agree	16	17	10	16	59
Total	45	48	34	25	153

Lack of understanding of BIM and its benefits

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	1	2	0	5
Disagree	4	4	0	0	9
Neutral	9	7	2	4	22
Agree	17	14	11	8	50
Strongly agree	13	22	19	13	67
Total	45	48	34	25	153

Resistance to change: Lack of skills development

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	1	2	0	5
Disagree	4	3	0	0	7
Neutral	6	5	4	1	17
Agree	22	21	9	13	65
Strongly agree	11	18	19	11	59
Total	45	48	34	25	153

Lack of BIM education

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	1	2	0	6
Disagree	4	5	4	0	13
Neutral	9	6	3	4	22
Agree	15	17	11	8	51
Strongly agree	15	19	14	13	61
Total	45	48	34	25	153

Lack of BIM knowledge in applying current technologies

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	3	1	2	0	6
Disagree	3	3	1	0	8
Neutral	10	6	6	2	24
Agree	13	17	8	10	48
Strongly agree	16	21	17	13	67
Total	45	48	34	25	153

Process Barriers

Legal issues (ownership of data)

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	2	2	0	6
Disagree	7	4	3	1	15
Neutral	20	16	11	8	56
Agree	10	15	13	9	47
Strongly agree	6	11	5	7	29
Total	45	48	34	25	153

Risks and challenges with the use of a single model (BIM)

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	2	1	0	5
Disagree	9	3	3	1	17
Neutral	16	14	10	7	47
Agree	15	16	14	9	54
Strongly agree	3	13	6	8	30
Total	45	48	34	25	153

Changing work processes

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	2	1	0	5
Disagree	5	4	2	0	11
Neutral	16	11	8	3	38
Agree	17	19	11	10	57
Strongly agree	6	12	12	12	42
Total	45	48	34	25	153

Lack of effective collaboration among project participants

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	2	1	0	5
Disagree	5	4	2	0	11
Neutral	16	11	8	3	38
Agree	17	19	11	10	57
Strongly agree	6	12	12	12	42
Total	45	48	34	25	153

Business Barriers

High Cost of implementation

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	4	3	0	8
Disagree	8	5	1	3	18
Neutral	11	8	6	2	27
Agree	19	21	15	13	68
Strongly agree	6	10	9	7	32
Total	45	48	34	25	153

Unclear benefits

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	1	4	1	8
Disagree	10	13	2	2	27
Neutral	18	12	6	1	38
Agree	10	14	16	10	50
Strongly agree	5	8	6	11	30
Total	45	48	34	25	153

Doubts about Return on Investment

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	1	2	1	5
Disagree	4	8	1	0	14
Neutral	17	14	5	4	40
Agree	16	17	17	13	63
Strongly agree	7	8	9	7	31
Total	45	48	34	25	153

Lack of contractual arrangements

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	2	2	0	6
Disagree	3	5	0	0	8
Neutral	15	14	10	3	42
Agree	20	14	13	11	58
Strongly agree	6	13	9	11	39
Total	45	48	34	25	153

Time and Cost of training

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	3	3	0	8
Disagree	1	2	2	1	7
Neutral	15	9	5	5	34
Agree	18	22	13	12	65
Strongly agree	9	12	11	7	39
Total	45	48	34	25	153

Complicated and time-consuming modelling process

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	2	4	0	8
Disagree	2	8	7	2	19
Neutral	13	8	2	2	26
Agree	22	14	11	11	58
Strongly agree	6	16	10	10	42
Total	45	48	34	25	153

Technical Barriers

Lack of BIM technical experts

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	3	4	0	9
Disagree	5	3	0	0	8
Neutral	8	10	3	6	28
Agree	18	19	13	10	60
Strongly agree	12	13	14	9	48
Total	45	48	34	25	153

Interoperability

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	2	5	0	8
Disagree	3	1	0	1	5
Neutral	19	18	10	4	52
Agree	18	15	13	8	54
Strongly agree	4	12	6	12	34
Total	45	48	34	25	153

Absence of standards and clear guidelines

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	3	3	0	8
Disagree	4	5	0	0	9
Neutral	10	12	7	3	33
Agree	22	16	13	10	61
Strongly agree	7	12	11	12	42
Total	45	48	34	25	153

Insufficient technology infrastructure

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	3	2	3	0	8
Disagree	4	6	2	2	14
Neutral	11	12	6	4	34
Agree	21	16	13	9	59
Strongly agree	6	12	10	10	38
Total	45	48	34	25	153

Current technology is enough

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	5	5	3	1	14
Disagree	15	6	4	3	28
Neutral	8	16	7	3	35
Agree	11	10	13	12	46
Strongly agree	6	11	7	6	30
Total	45	48	34	25	153

Organization Barriers

Lack of Senior Management support

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	4	2	0	8
Disagree	7	1	0	0	8
Neutral	7	12	1	6	27
Agree	16	11	16	9	52
Strongly agree	13	20	15	10	58
Total	45	48	34	25	153

Difficulties in managing the impacts of BIM

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	4	2	0	8
Disagree	8	4	0	0	12
Neutral	14	14	5	7	41
Agree	14	14	16	10	54
Strongly agree	7	12	11	8	38
Total	45	48	34	25	153

Absence of Other Competing Initiatives

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	2	2	0	6
Disagree	4	4	1	0	9
Neutral	21	18	12	5	57
Agree	12	11	9	11	43
Strongly agree	6	13	10	9	38
Total	45	48	34	25	153

Unwillingness to change

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	2	2	0	6
Disagree	5	6	1	0	12
Neutral	12	10	2	4	29
Agree	16	12	14	9	51
Strongly agree	10	18	15	12	55
Total	45	48	34	25	153

Magnitude of Change / Staff turnover

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	5	2	0	9
Disagree	6	3	3	0	12
Neutral	14	17	5	6	43
Agree	16	9	13	11	49
Strongly agree	7	14	11	8	40
Total	45	48	34	25	153

Construction Insurance

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	3	4	0	9
Disagree	6	6	2	0	14
Neutral	22	11	7	5	46
Agree	5	14	13	9	41
Strongly agree	10	14	8	11	43
Total	45	48	34	25	153

Market Barriers

Lack of client/government demand

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	3	3	0	8
Disagree	6	6	3	1	16
Neutral	12	7	2	5	27
Agree	16	13	11	9	49
Strongly agree	9	19	15	10	53
Total	45	48	34	25	153

The market is not ready yet

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	4	4	4	0	12
Disagree	11	6	10	5	32
Neutral	11	16	4	6	38
Agree	14	8	8	7	37
Strongly agree	5	14	8	7	34
Total	45	48	34	25	153

Lack of publicity and awareness

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	2	3	0	7
Disagree	4	6	4	2	16
Neutral	8	9	3	2	23
Agree	23	16	14	12	65
Strongly agree	8	15	10	9	42
Total	45	48	34	25	153

Main Factors Influencing the Adoption of BIM

External Push

Government support and pressure in the implementation of BIM

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	3	5	2	0	10
Disagree	7	3	1	2	14
Neutral	7	7	1	2	17
Agree	12	9	11	8	40
Strongly agree	16	24	19	13	72
Total	45	48	34	25	153

Client pressure and demand the application of BIM in their projects

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	6	2	0	9
Disagree	4	3	1	1	10
Neutral	11	5	3	3	22
Agree	14	15	12	9	50
Strongly agree	15	19	16	12	62
Total	45	48	34	25	153

Provide education at university level

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	4	1	0	6
Disagree	2	3	3	0	8
Neutral	9	8	6	6	30
Agree	15	15	11	7	48
Strongly agree	18	18	13	12	61
Total	45	48	34	25	153

Developing BIM data exchange standards, rules and regulations

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	5	2	0	8
Disagree	3	1	1	0	5
Neutral	12	8	6	5	32
Agree	12	19	10	6	47
Strongly agree	17	15	15	14	61
Total	45	48	34	25	153

Providing guidance on use of BIM

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	5	2	0	9
Disagree	2	2	1	0	5
Neutral	10	1	3	5	20
Agree	15	24	14	7	60
Strongly agree	16	16	14	13	59
Total	45	48	34	25	153

Contractual arrangements

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	5	2	0	9
Disagree	1	1	1	0	3
Neutral	13	4	5	7	30
Agree	19	22	12	7	60
Strongly agree	10	16	14	11	51
Total	45	48	34	25	153

BIM required by other project parties

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	5	2	0	8
Disagree	3	1	0	0	4
Neutral	12	6	5	7	31
Agree	18	19	10	6	53
Strongly agree	11	17	17	12	57
Total	45	48	34	25	153

Competitive pressure

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	3	5	2	0	10
Disagree	3	1	0	0	4
Neutral	12	10	6	5	34
Agree	18	19	10	10	57
Strongly agree	9	13	16	10	48
Total	45	48	34	25	153

Promotion and awareness of BIM

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	5	1	0	7
Disagree	2	2	1	0	5
Neutral	17	7	7	5	37
Agree	13	18	11	9	51
Strongly agree	12	16	14	11	53
Total	45	48	34	25	153

Clients provide pilot project for BIM

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	5	1	0	7
Disagree	1	2	0	2	5
Neutral	13	6	7	3	30
Agree	18	18	14	10	60
Strongly agree	12	17	12	10	51
Total	45	48	34	25	153

Collaboration with universities (Research collaboration and curriculum design for students)

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	5	1	0	8
Disagree	1	2	2	0	5
Neutral	14	6	3	6	30
Agree	14	19	12	7	52
Strongly agree	14	16	16	12	58
Total	45	48	34	25	153

Perceived benefits from BIM to client

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	5	1	0	8
Disagree	1	1	0	0	2
Neutral	12	9	5	6	33
Agree	16	17	14	7	54
Strongly agree	14	16	14	12	56
Total	45	48	34	25	153

Internal Push

Top management support

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	4	2	0	7
Disagree	1	3	0	0	4
Neutral	9	4	5	5	24
Agree	15	15	12	7	49
Strongly agree	19	22	15	13	69
Total	45	48	34	25	153

Cultural change

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	4	2	0	7
Disagree	1	3	0	0	4
Neutral	9	3	7	4	24
Agree	21	18	11	5	55
Strongly agree	13	20	14	16	63
Total	45	48	34	25	153

Improving built output quality

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	4	2	0	7
Disagree	1	3	0	0	4
Neutral	10	0	5	6	22
Agree	21	21	15	6	63
Strongly agree	12	20	12	13	57
Total	45	48	34	25	153

Perceived benefits from BIM

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	0	4	2	0	6
Disagree	1	2	0	0	3
Neutral	10	3	4	4	22
Agree	21	22	13	9	65
Strongly agree	13	17	15	12	57
Total	45	48	34	25	153

Technical competence of staff

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	2	4	2	0	8
Disagree	1	3	0	0	4
Neutral	8	4	5	6	24
Agree	24	22	13	7	66
Strongly agree	10	15	14	12	51
Total	45	48	34	25	153

Financial resources of organization

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	0	4	2	0	6
Disagree	1	3	1	0	5
Neutral	9	6	7	5	28
Agree	24	18	13	9	64
Strongly agree	11	17	11	11	50
Total	45	48	34	25	153

Desire for innovation with competitive advantages and differentiation in the market

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	0	3	2	0	5
Disagree	1	4	0	0	5
Neutral	13	8	8	3	33
Agree	20	15	13	9	57
Strongly agree	11	18	11	13	53
Total	45	48	34	25	153

Improving the capacity to provide whole-life value to client

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	3	2	0	6
Disagree	2	3	0	0	5
Neutral	12	8	9	4	34
Agree	18	20	12	9	59
Strongly agree	12	14	11	12	49
Total	45	48	34	25	153

Safety into the construction process (reduce risk of accident

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	0	6	1	0	7
Disagree	6	4	1	0	11
Neutral	11	9	9	5	35
Agree	19	17	15	12	63
Strongly agree	9	12	8	8	37
Total	45	48	34	25	153

BIM training program to staff

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	5	1	0	7
Disagree	0	2	0	0	2
Neutral	10	2	7	4	24
Agree	20	21	12	8	61
Strongly agree	14	18	14	13	59
Total	45	48	34	25	153

Requirement for staff to be BIM competent

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	4	1	0	6
Disagree	2	3	1	0	6
Neutral	13	5	5	5	29
Agree	15	22	15	10	62
Strongly agree	14	14	12	10	50
Total	45	48	34	25	153

Continuous investment in BIM

	Not using BIM	BIM user	BIM expert	BIM researcher	Total
Strongly disagree	1	5	1	0	7
Disagree	1	2	0	0	3
Neutral	15	4	6	2	28
Agree	19	19	14	10	62
Strongly agree	9	18	13	13	53
Total	45	48	34	25	153